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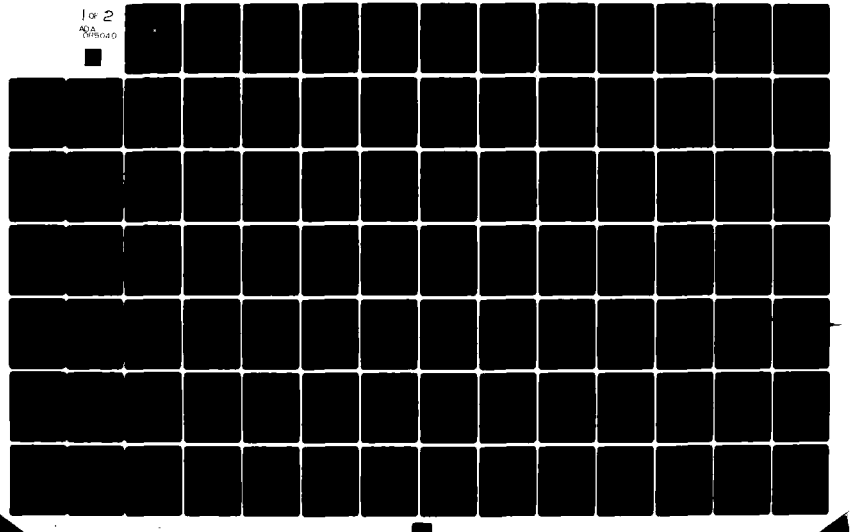

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THESIS

SEA LEVEL VARIATIONS
AT MONTEREY, CALIFORNIA

BY

Dale E. Bretschneider

March 1980

Thesis Advisor: W.C. Thompson

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A085 040 / 3. RECIPIENT'S CATALOG NUMBER (9)
4. TITLE (and Subtitle) (6) Sea Level Variations at Monterey, California.	5. TYPE OF REPORT & PERIOD COVERED Masters Thesis; March 1980
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) LT. Dale E. Bretschneider, NOAA	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	12. REPORT DATE (11) March 1980
	13. NUMBER OF PAGES ~~105~~ (12) 106
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Sea level variability; Oceanic and atmospheric effects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Seasonal, monthly, weekly, and hourly sea level variability at Monterey, California is described and the oceanic and atmospheric processes which cause these variations are examined. Monthly mean sea level anomalies at Monterey are significantly correlated with those observed at tide stations as distant as Prince Rupert, Canada and Callao, Peru, indicating that these anomalies are related to large scale rather than to strictly local atmospheric or oceanic

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changes. Multiple regression analysis indicates that monthly anomalies of atmospheric pressure, sea surface temperature, and meridional wind stress account for much of the observed monthly sea level variability. Sea level elevations at Monterey, when adjusted for the atmospheric pressure (barometric) effect, show a seasonal high in winter and a minimum in spring. These seasonal variations are in phase with those of nearby steric height observations. There is also good agreement between weekly mean sea level and steric height observations in a time-series sense. Because of the close agreement between sea level and steric height, and the high correlation of Monterey sea level with that at nearby tide stations, steric height and sea level variations both must be related to variations in the geostrophic current flow.

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Sea Level Variations
At Monterey, California

by

Dale Emil Bretschneider
Lieutenant, NOAA
B.S., Humboldt State University, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
March 1980

Author Dale E. Bretschneider

Approved by: Warren C Thompson
Thesis Advisor

Second Reader

Chairman, Department of Oceanography

William M. Tolles
Dean of Science and Engineering

ABSTRACT

Seasonal, monthly, weekly, and hourly sea level variability at Monterey, California is described and the oceanic and atmospheric processes which cause these variations are examined. Monthly mean sea level anomalies at Monterey are significantly correlated with those observed at tide stations as distant as Prince Rupert, Canada and Callao, Peru, indicating that these anomalies are related to large scale rather than to strictly local atmospheric or oceanic changes. Multiple regression analysis indicates that monthly anomalies of atmospheric pressure, sea surface temperature, and meridional wind stress account for much of the observed monthly sea level variability. Sea level elevations at Monterey, when adjusted for the atmospheric pressure (barometric) effect, show a seasonal high in winter and a minimum in spring. These seasonal variations are in phase with those of nearby steric height observations. There is also good agreement between weekly mean sea level and steric height observations in a time-series sense. Because of the close agreement between sea level and steric height, and the high correlation of Monterey sea level with that at nearby tide stations, steric height and sea level variations both must be related to variations in the geostrophic current flow.

TABLE OF CONTENTS

I. INTRODUCTION 9

A. EARLIER STUDIES ON SEA LEVEL VARIATIONS 10

B. OCEAN AND ATMOSPHERIC PROCESSES NEAR MONTEREY 11

II. DESCRIPTION OF DATA 14

A. MONTEREY SEA LEVEL DATA 16

1. Tide Gages 16

2. Data Processing and Reduction 16

3. Merging of Analog and Digital Tide Data 17

4. Long Period Sea Level Changes 19

B. OCEAN AND ATMOSPHERIC DATA 20

III. SEA LEVEL AT MONTEREY 22

A. MEANS AND VARIATIONS 22

1. Hourly Sea Level 22

2. Monthly Mean Sea Level 27

B. RELATION TO OTHER PACIFIC COAST TIDE STATIONS 32

IV. CAUSES OF SEA LEVEL VARIATIONS AT MONTEREY 47

A. CORRELATION ANALYSIS 47

B. REGRESSION ANALYSIS 53

C. SPECTRUM ANALYSIS 57

D. DYNAMIC HEIGHT 64

V. SUMMARY 68

LIST OF REFERENCES 70

APPENDIX A Missing Hourly Sea Level Data 73

APPENDIX B Monthly Mean Oceanic and Atmospheric Observations 74

DISTRIBUTION LIST 102

LIST OF TABLES

1. Inter-Correlation of Monthly Sea Level Anomalies for Selected West Coast Tide Stations 39

2. Inter-Correlation of Monthly Sea Level Anomalies and Monthly Anomalies of Various Ocean and Atmospheric Variables 48

3. Results of Multiple Regression Analysis 54

4. Results of Multiple Regression Analysis By Season 56

LIST OF FIGURES

1. Map of Monterey Bay Region Showing Data Sources 15

2. Comparison of Hourly Tide Measurements From Digital and Analog Gages For Calendar Year 1974 18

3. Typical Daily Tidal Cycle at Monterey 23

4. Difference Between Observed and Predicted Hourly Tide Heights 25

5. Difference Between Observed and Predicted Hourly Tide Heights By Month 26

6. Annual Cycle of Mean Monthly Sea Level 28

7. Monterey Monthly Sea Level Means and Anomalies 29

8. Autocorrelation Function for Monthly Sea Level at Monterey 33

9. Selected Tide Stations Along the West Coasts of North and South America 34

10. Time-Series of Monthly Sea Level Anomalies for Selected West Coast Tide Stations 35

11. Correlation of Monthly Sea Level Anomalies at Selected West Coast Tide Stations Relative to Monterey 40

12. Time-Distance Plot of Monthly Sea Level Anomalies at Selected West Coast Tide Stations 42

13. Adjusted and Unadjusted Monthly Mean Sea Level at Monterey 51

14. Response Function for 30-day Running Mean Filter 58

15. Spectra of Six-Hourly Atmospheric Pressure and Unadjusted Sea Level 59

16. Spectra of Six-Hourly Meridional Wind Stress and Adjusted Sea Level 62

17. Seasonal Cycle of Sea Level and Dynamic Height 65

18. Time-Series of Weekly Mean Sea Level and Dynamic Height 67

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. Warren C. Thompson as thesis advisor for his guidance and assistance throughout the course of this study. Mr. Jerry Norton provided invaluable assistance in the reduction of the Monterey sea level data and Dr. C. N. K. Mooers reviewed the manuscript and provided advice. All are with the Department of Oceanography of the Naval Postgraduate School.

The author wishes to express his appreciation to Dr. Douglas R. McLain for advice, assistance and encouragement throughout the course of this work. Grateful appreciation is extended to Mr. Andrew Bakun for his advice and assistance and to Mr. Gunter Seckel for his interest and support. The patient assistance of Mrs. Magge Lazanoff and Ms. Hilda Talbert with the manuscript is gratefully acknowledged. All are colleagues at the Pacific Environmental Group, National Marine Fisheries Service, Monterey, California.

The assistance of Mr. C. I. Thurlow and Mr. J. R. Hubbard of the National Ocean Survey, Rockville, Maryland, in the procurement of data is gratefully recognized.

I. INTRODUCTION

The study of sea level and its changes has interested man for many years. Historical sea level time-series data are unique among marine data sources in that they have been obtained continuously and inexpensively over periods of decades or longer at a large number of fixed coastal locations worldwide. Sea level records include not only periodic fluctuations due to astronomic tides but also non-tidal sea level fluctuations resulting from various oceanic and atmospheric processes. The latter can be isolated as anomalies by filtering out the astronomic tides, thus making measurements of sea level useful as a spacially integrated index of nearshore and offshore ocean and atmospheric changes.

This paper examines the character of sea level anomalies at Monterey, California and inquires into the relative importance of the large-scale atmospheric and ocean processes which affect non-tidal sea level measurements there. Sea level variability on seasonal, monthly, weekly, and hourly time scales is described, as are the physical processes which cause these changes. An understanding of these processes will allow the use of the long series of sea level data to reconstruct historical changes in the oceanographic environment of the California Current system, which, in turn, will aid in understanding past changes in distribution, abundance, and availability of marine fish populations.

This study was supported by the National Marine Fisheries Service (NMFS) which is interested in the use of sea level data for identification of anomalous environmental periods and monitoring of changes in oceanographic conditions offshore.

A. EARLIER STUDIES ON SEA LEVEL VARIATIONS

Sea level variations along the Pacific coast and their relationship to various environmental phenomena have been examined from a number of different points of view. In addition to the well-understood astronomically induced periodicities, it is widely recognized that coastal sea level measurements may be influenced by:

1) changes in atmospheric pressure over the ocean surface,

2) changes in average density of the sea water column,

3) redistribution of water mass due to wind stress,

4) wind set-up or set-down against the coast due to storms,

5) subsidence or uplift of the land upon which the tide gage is located,

6) long period astronomic tides,

7) changes in total mass of water in the oceans associated with the glacial ice budget, and

8) wind waves and swell.

These physical processes are discussed by Montgomery (1938). LaFond (1939) found close agreement between weekly mean sea level measured at La Jolla, California and the geopotential topography offshore, thus directly relating ocean currents to sea level. Jacobs (1939) suggested that the relationships observed by LaFond were not entirely due to changes in the density of surface water but rather to actual slopes induced by wind-driven water transport along the coast. Pattullo, et. al. (1955) found that south of 40° N in the North Pacific Ocean, the seasonal variation of steric elevation and sea level are in phase, both having a maximum elevation in late summer or early fall and a minimum elevation in winter. This they took as a consequence of seasonal heating and cooling. These investigators further found that seasonal variations in sea level north of 40° N along the northwest coast of the United States could not be explained by steric considerations alone, suggesting that non-isostatic processes such as wind and currents can lead to appreciable regional

deviations. Roden (1960) used autocorrelation and spectral techniques to examine the relationship between monthly mean sea level pressure, wind, and sea surface temperature (SST) at several stations along the Pacific coast. He found good coherence between anomalies of sea level and atmospheric pressure, moderate to poor coherence between SST and sea level depending on the location of the station, and some coherence between anomalies of sea level and the north-south component of the geostrophic wind. Sturges (1974) found high correlations between occasional steric observations and 3-day mean sea levels at Neah Bay, Washington and San Diego, California. Reid and Mantyla (1976) demonstrated that the winter increase in seasonal sea level elevation along the northern north Pacific coast results from increased overall flow in the subarctic cyclonic gyre.

B. OCEAN AND ATMOSPHERIC PROCESSES NEAR MONTEREY

The California Current is a broad, diffuse, southward flowing eastern boundary current. The strength of the current is affected by the winds over the current which, in turn, are controlled by the strength and location of the Aleutian low-pressure cell located over the Aleutian Islands, the Pacific high pressure cell located mainly over the ocean east of the Hawaiian Islands, and the thermal low-pressure cell located over the western United States. During the spring and summer months the Aleutian low weakens and the Pacific high intensifies and moves northward. Winds over the current during this period are mainly from the northwest and are strongest when the Pacific high and thermal low pressure cells are closest together and relatively intense. Winds weaken or change direction when this pressure gradient decreases. The seasonal change in strength and location of these pressure cells thus causes seasonal changes in the winds (Reid, Roden, and Wyllie, 1958).

Skogsberg (1936) described three distinct seasonal phases in his study of the hydrography of Monterey Bay. The calendar year opens in the countercurrent or Davidson Current phase. In late fall and early winter of most years northerly winds are weak and variable, and a northward flowing countercurrent usually forms at the surface along the central California coast. This current is reinforced by intermittent periods of southerly winds during winter. The general north northwest-south southeast trend of the coastline and the movement of surface water to the right of the wind due to the Ekman effect cause onshore transport of surface waters and piling up against the coast. Minimal solar radiation and strong vertical mixing of surface waters by winter storms decrease sea surface temperatures to a seasonal minimum during January or February. While SST's decline during the Davidson Current period, temperatures at deeper levels slowly increase due to advection of warm waters from the south. For example, temperatures at 50 meters depth reach a seasonal maximum during December and January (Skogsberg, 1936; Bolin and Abbott, 1963). The end of the Davidson Current period is variable and difficult to pinpoint. About March, the offshore high pressure cell intensifies and northwest winds become frequent. The Ekman deflection causes offshore transport of surface water. In the nearshore region, some of this water is replaced by cold, nutrient-rich subsurface water upwelled from the upper hundred or so meters. Upwelling is strongest when northerly winds are strongest, and usually reaches a maximum near Monterey in May or June (Bakun, 1975). By August, northerly winds begin to slacken and the increased solar radiation of late spring and summer results in a steady rise in SST that usually continues through September. September and October bring about a period of calmer winds that Skogsberg (1936) called the oceanic period. With a slackening of windstress, the cool, upwelled water begins to sink and is replaced by warmer surface water from offshore. Coastal SST's rise to their highest seasonal values and strong vertical temperature gradients form (Bolin and Abbott, 1963).

To summarize, the oceanographic regime off Monterey is marked by three distinct periods: The Davidson Current period, occurring during November through February, has weak northerly winds, strong winter storm events, northward current flow, and onshore transport of surface water. The upwelling period, occurring in March through August, has strong northwest winds, southward current flow, offshore transport of surface water, and upwelling of cool, nutrient-rich water. The oceanic period, occurring during September and October, is a period of calm between the northerly winds of the upwelling period and the southerly winds of winter. During this period, surface temperatures increase and strong vertical temperature gradients form. These are the average seasonal characteristics in the meteorological and oceanic regimes affecting Monterey, however, there are marked year-to-year differences in both timing and intensity of the events described.

II. DESCRIPTION OF DATA

Recorded tide data from the tide station at Monterey, California were chosen for analysis because the gage lies in a coastal area of interest to the NMFS and is exposed to open ocean conditions with no nearby river discharge to affect sea level measurements. The Monterey gage is the only primary tide station maintained by the National Ocean Survey (NOS) between San Francisco and Avila, and thus fills a large data gap along the central California coast. The Monterey station has been operated continuously since 1963 by the Naval Postgraduate School under the direction of Dr. Warren C. Thompson but the time-series data were not previously fully analyzed.

Monterey Bay is located about 120 km south of San Francisco, California. The bay, which is bisected by a deep submarine canyon, is a large, semi-elliptical coastal feature measuring about 37 km wide at the mouth and about 19 km from the mouth to the innermost point. The tide station is located along the southern edge of the bay near the end of Monterey Municipal Wharf #2 in a water depth of approximately 6.8 m. Because of the open shape of the bay and the narrow width of the continental shelf, tide measurements obtained here are presumed to fully represent those of the open coast.

In addition to sea level data, meterological and oceanographic data representative of the Monterey area, including surface atmospheric pressure data, geostrophic wind data, surface salinity and temperature data, and deep hydrocast data were used in this study. The general proximity of the various data sources allowed direct comparison of variables with minimal problems resulting from spatial distortion. Figure 1 shows the location from which each of the data sources were derived, along with the nearby bathymetry.

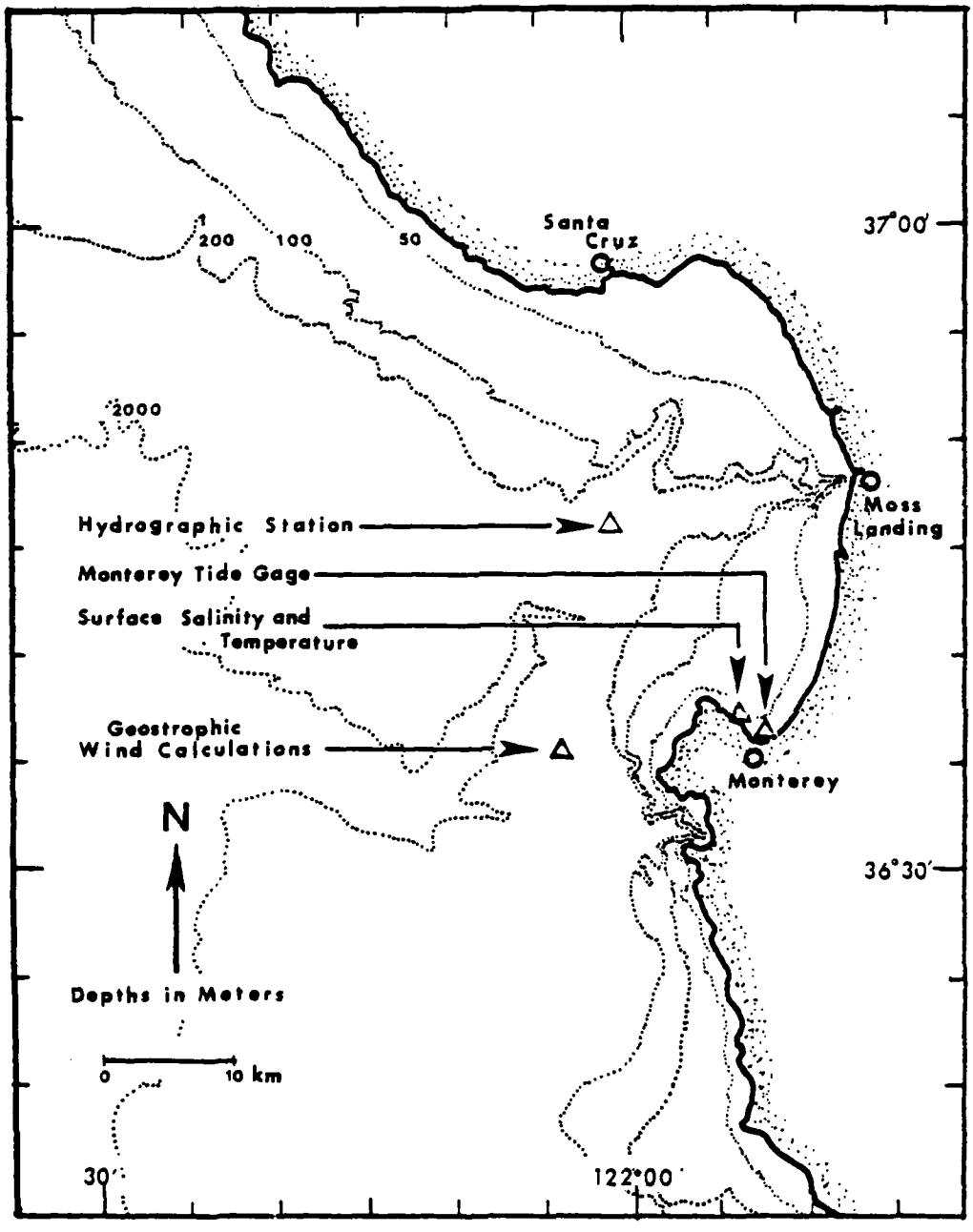


Figure 1. Map of Monterey Bay Region Showing Data Sources

A. MONTEREY SEA LEVEL DATA

1. Tide Gages

A standard recording tide gage, which traces tide heights continuously on a strip chart, was installed at the Monterey tide station by NPS personnel in June 1963. This analog system is entirely mechanical and is highly dependable when maintained properly. A drum-mounted strip chart is rotated by a spring-driven clock mechanism, and a pencil records sea level changes by means of a float-pulley system. A second instrument, a Fischer-Porter digital tide gage, was installed adjacent to the analog gage by the National Ocean Survey in November 1973. This is an electrically operated system which punches digital data on foil tape. Both gages use the same 21.6 cm diameter float and have operated simultaneously since November 1973. The stilling well, which serves as a low pass filter for oscillations with periods greater than a minute, consists of a 30.5 cm diameter steel pipe with a 2.5 cm diameter orifice at the bottom. Both gages are checked for accuracy of time and height and are annotated about five times per week.

2. Data Processing and Reduction

Continuous tide traces obtained from the analog gage during the period July 20, 1963 through December 31, 1974 were manually digitized for use in this study. Digitization was performed by Ocean Data Systems, Inc., Monterey, CA under contract to the NMFS and with NPS guidance. Datums were reviewed and data were reduced to hourly sea level heights using standard NOS procedures (Coast and Geodetic Survey, 1965). Data from the digital gage for the period January 1, 1974 through September 31, 1976 were processed for hourly heights by the NOS and provided for use in this study. Data from both gages were recorded in feet and later converted to centimeters in this study. The hourly heights are resolved to the nearest 0.1 foot (3.0 cm) and times of observation (Pacific Standard Time) are accurate to within six minutes. A small percentage of the hourly sea level data were missing, either rejected as erroneous or lost due to equipment malfunctions.

As a result some monthly means contain less than a full month of data. Missing data of duration of a day or longer are listed in Appendix A.

All hourly heights were measured relative to the station datum established by the NOS in November, 1973. Mean sea level for the period 1963 through 1978 lies at 184.4 cm and the National Geodetic Vertical Datum lies 182.88 cm above the station datum.

3. Merging of Analog and Digital Tide Data

To obtain the longest possible continuous tide record, it was necessary to merge the analog and the more recent digital data sets. Before the data sets were combined, the response of the two gages was analyzed by comparing the hourly heights from both tide records for the calendar year 1974. The correlation coefficient between the analog and digital data sets exceeds 0.99, as anticipated. The regression equation for the two sets of hourly heights is $Y = 1.48 \text{ cm} + 0.98X$, where X refers to digital data and Y refers to analog data in cm.

Figure 2 shows a histogram of the difference (digital minus analog data) between the two sets of hourly sea levels for the calendar year 1974. The mean difference was found to be -0.06 cm. The frequency distribution of the differences resembles a normal distribution, with a standard deviation of 3.7 cm. Nearly all of the differences are attributed to the fact that the digital data were recorded as instantaneous values, which can include short-term sea level fluctuations such as long waves or seiches, whereas in the analog data these short-term fluctuations were filtered out by manually smoothing the tide curve before digitizing.

It was concluded that differences between the two data sets were negligible, and that the analog and digital data could be combined without bias. Thus, analog data from the period July 20, 1963 through December 31, 1974 were combined with digital data from the period January 1, 1975 through August 31, 1976 to form a 13-year time series containing a total of 107,954 hourly observations.

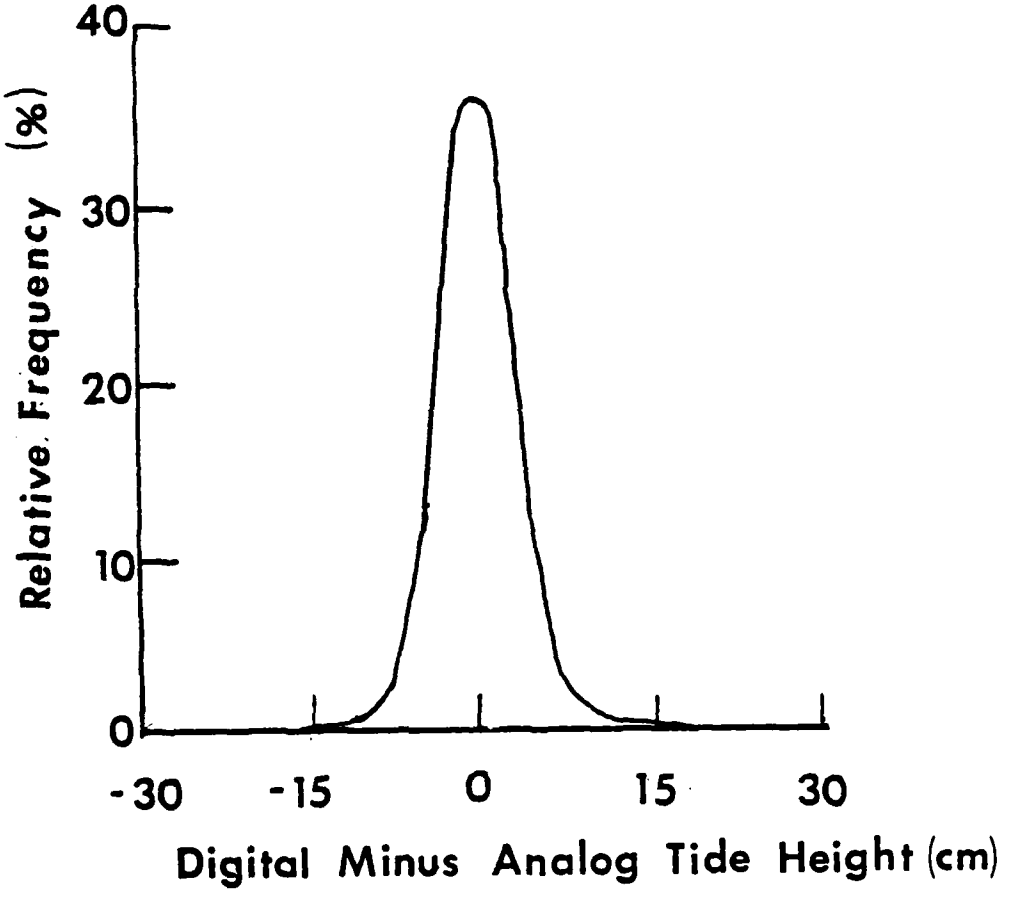


Figure 2. Comparison of Hourly Tide Measurements From Digital and Analog Gages for Calendar Year 1974

4. Long Period Sea Level Changes

Tide gages show the height of the sea level relative to land. Thus, changes in mean sea level over periods of years or decades can result from the addition or removal of water from the oceans due to global climatic variations, from subsidence or emergence of the land upon which the gage is located, or from long-period astronomic tides. For example, some long-period trends in sea level records, such as the rise in sea level in Panama described by Roden (1963) or the drop in sea level in the Juneau, Alaska area described by Hicks (1973) clearly result from local or regional land subsidence or uplift.

To determine trends in the Monterey sea level record during the period 1963 through 1978, the time-series of monthly means was analyzed using a least-squares fit. This analysis yielded a relative rise in sea level of 0.01 cm/year. The variability in sea level due to oceanographic and meterological processes thus greatly exceeds measured trends. Accordingly, the effects of trends were neglected in this study.

Of the long period astronomic tides, the nodal tidal constituent, which results from the changing declination of the moon over a period of 18.61 years, has the greatest amplitude. The theoretical amplitude of this constituent varies with latitude, with maximum effects at the equator and the poles and minimum effects near the latitudes 35° N and 35° S (Lisitzin, 1974). A second significant long period constituent, the annual solar tide, has an amplitude approximately one fifth of the nodal tide component. The effects of this tidal constituent vary with latitude in a manner similar to that of the nodal tide. Monterey, located near 36° N, is in a region where the ranges of both of these long period tides are about 1 cm, so these effects were neglected in this study.

B. OCEAN AND ATMOSPHERIC DATA

The computed atmospheric pressure and wind data used in this study were derived from six-hourly synoptic surface pressure fields prepared by Fleet Numerical Oceanography Center (FNOC). The pressure fields, arranged on a grid with a mesh length of 3 degrees latitude, were used to compute geostrophic winds, from which windstress, Ekman transport, and Sverdrup transport estimates were calculated at a deep water site approximately 14 km west of Monterey (Figure 1). A complete description of the methods and computations used in these calculations is given by Bakun (1975). Briefly, the geostrophic wind was computed at the point 36.6° N, 122.1° W and an estimate of the wind near the sea surface was made by rotating the geostrophic wind vector 15 degrees to the left and reducing its magnitude by 30%. The surface wind stress was computed and the wind stress vector was resolved into north-south (meridional or alongcoast) and east-west (zonal or acrosscoast) components. Ekman transport was computed and offshore-onshore transport was determined by resolving the vector component perpendicular to the general trend of the coastline. Sverdrup transport was calculated as described by Nelson (1977).

The surface temperature and salinity data were obtained from samples taken daily at Hopkins Marine Station of Stanford University during the period January 1963 to May 1975 (Scripps Institution of Oceanography, 1963 to 1976). SST data from June 1975 to December 1978 were taken at the Monterey tide station by Mr. Jerry Norton of the Naval Postgraduate School. Salinity data from Hopkins are not available later than May 1975.

Monthly means and anomalies of sea level, and of the ocean and atmospheric data described in the above sections are presented graphically and in tabular form in Appendix B.

To examine the relationship between sea level and dynamic height, a series of hydrographic cast data were assembled for a station located in mid-Monterey Bay,

about 19 km northwest of the tide station (Figure 1). This hydrographic station is located near the mouth of the Monterey submarine canyon where the water depth is over 900 meters. The hydrographic cast data were taken semi-monthly by Hopkins Marine Station. Sampling during the first years of the program was limited to the upper 50 meters of the water column but in 1968 the sampling depth was increased to over 500 meters (Hopkins Marine Station, 1968-1973). Sampling was discontinued by Hopkins in December 1973 and was resumed on a semi-monthly basis by Moss Landing Marine Laboratory from July 1974 to June 1978 (Broenkow, et al., 1975 and 1976; Lasley, 1977; Chinburg, et al., 1978). Hydrographic data for the ten-year period January 1968 through December 1977 were digitized, and long-term monthly mean dynamic heights and dynamic height anomalies were calculated.

III. SEA LEVEL AT MONTEREY

The tides at Monterey are mixed, predominantly semi-diurnal, and are composed of two high and two low waters per 24.8 hour tidal cycle (Figure 3). Analysis of the 13 years of hourly data show that the largest daily tide range recorded, 274.3 cm, occurred on December 20, 1968. The maximum water level during the period of record, 329.2 cm above station datum, occurred on January 18, 1973 and was 30.5 cm above the predicted tide for that time. The minimum water level, 36.6 cm above station datum, occurred on June 11, 1968 and was 15.2 cm below the predicted tide. This analysis does not include data for March 28, 1964 because of a tsunami resulting from the Alaskan earthquake.

It is recognized that the time series of hourly sea levels could be analyzed for the occurrence, amplitude, and duration of anomalous sea level events. This was done by Maixner (1973) who examined Monterey sea level anomalies for the year 1971. It was decided for this study, however, to concentrate on variations identified in mean monthly sea level data and on their atmospheric and oceanographic causes; weekly mean and six-hourly sea level data are also examined in a limited way. The statistical characteristics of hourly deviations from the predicted sea level are also examined.

A. MEANS AND VARIATIONS

1. Hourly Sea Level

To analyze non-tidal sea level variations, which are small compared to the normal tide range in this area, the tidal signal must be removed from the data. This can be done by averaging, filtering, or subtracting predicted tides from the data. The latter method was used in this study. The Tide Predictions Branch of the NOS performed a harmonic analysis of 365 days of hourly Monterey tide heights and isolated 37 harmonic constituents. These constituents are listed by Maixner

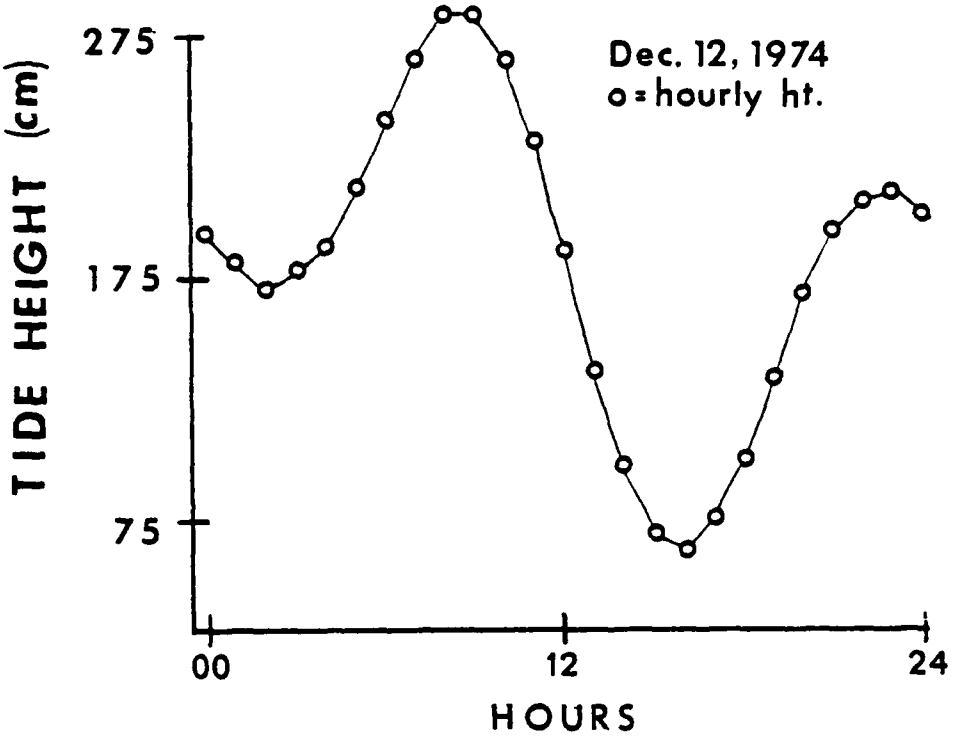


Figure 3. Typical Daily Tidal Cycle at Monterey

(1973). Using the 20 constituents whose amplitudes were greater than 0.61 cm, the NOS computed predicted hourly tide heights for the period of record. Predicted hourly heights were then subtracted from the 13 years of observed hourly heights to yield non-astronomic residuals. The frequency of occurrence of these sea level differences (observed minus predicted), which total nearly 108,000 values, approximates a normal or Gaussian distribution (Figure 4). 94.5% of the observations lie within 15.2 cm (0.5 foot) of the predicted tide and 99.9% lie within 30.5 cm (1.0 foot). The maximum observed difference was 39.6 cm. The standard deviation of the differences was 8.7 cm, skewness -0.02, and kurtosis 3.2.

The distribution of hourly differences describes non-tidal sea level variations over a 13 year period but gives no information about seasonal variation. Does the frequency distribution change from month to month? Are distributions for winter months the same as those for summer? To define the seasonal change, curves were generated using data from 8,200 to 9,800 observations for each of the 12 months of the year and these are shown in Figure 5. The frequency distribution of non-tidal sea level fluctuations is seen in the figure to change seasonally. In April, for example, 73% of the observed sea levels were lower than predicted, but in September, 81% of the observed data were greater than predicted. From March thru May, observed sea levels tend to be lower than predicted sea levels, probably due to offshore Ekman transport, SST, and atmospheric pressure effects as discussed in another section. From July through January, observed sea levels are greater than predicted due to atmospheric pressure and thermal effects during summer and fall, and to onshore transport, pressure, and thermal effects during the Davidson Current Period in December and January.

The distributions for winter months are wider and less peaked than those of summer months, indicating greater variability and larger non-tidal events. The distributions for July and August are notably narrow and peaked in contrast.

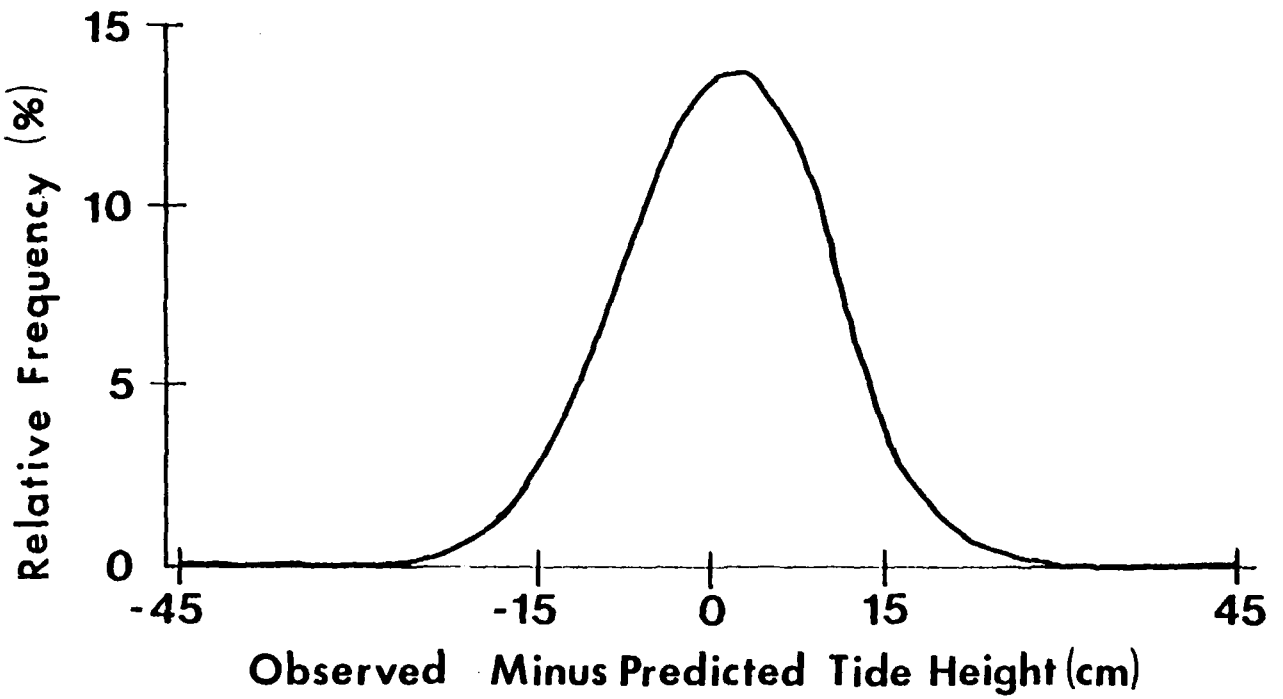


Figure 4. Difference Between Observed and Predicted Hourly Tide Heights (1963-1976)

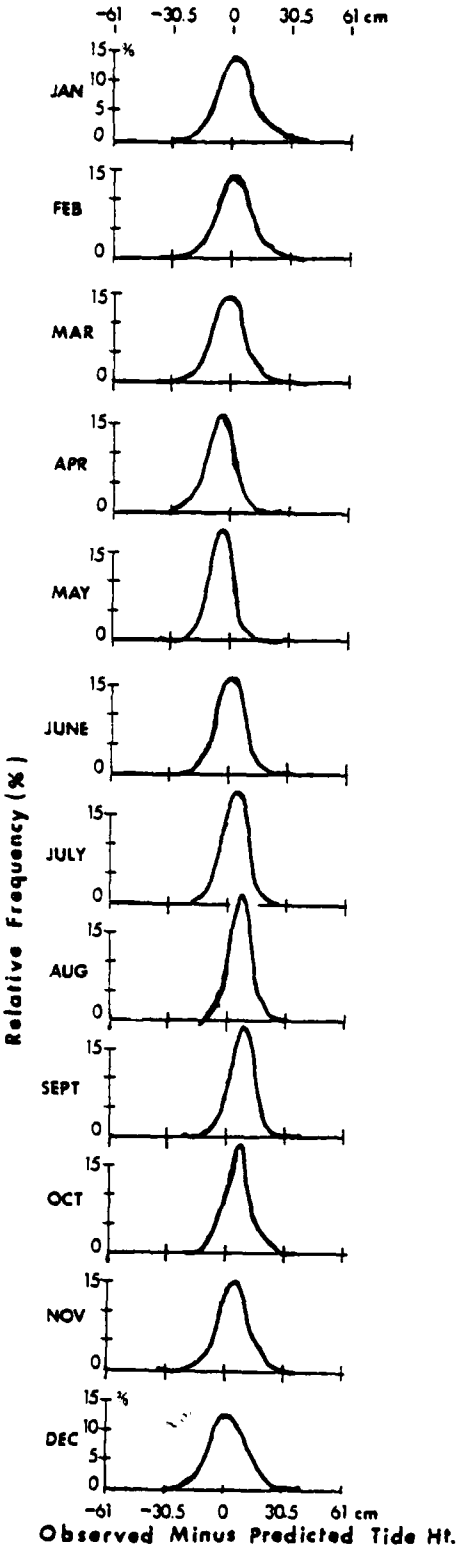


Figure 5. Difference Between Observed and Predicted Hourly Tide Heights by Month (1963-1976)

2. Monthly Mean Sea Level

Averaging over intervals of weeks to months removes the effects of the principal diurnal, semi-diurnal, and other short-term tidal components from the data, reduces large quantities of data to manageable size, and emphasizes time scales important for many marine biological processes.

The monthly means were calculated for the period July 1963 through August 1976 by the author, and for the period September 1976 through December 1978 by the NOS. Figure 6 shows the long term monthly means, standard deviations, and extreme monthly sea levels based on the 16-year period 1963 to 1978. Mean sea level is seen to be lowest in April and highest in September, with a mean annual range of 13.6 cm. Variability is highest during winter months, with monthly standard deviations during winter being almost double those for summer. The range between maximum and minimum monthly values reaches a high of 21.0 cm in January and a low of 8.5 cm in August.

Monthly sea level anomalies were calculated as differences between the monthly mean and the long-term mean for the same month. Calculation of anomalies in this manner removes the annual cycle from the data and allows direct comparison of month-to-month variability. Monthly mean sea levels and their anomalies are shown in tabular and graphical form in Figures 7A-7C. In these figures extreme monthly sea level anomalies are shown to range from -10.8 cm in December 1975 to +10.7 cm in January 1978. Periods of anomalously high sea level occurred during 1969, 1972-1973, 1976-1977, and early 1978, and periods of anomalously low sea level occurred in 1964, 1970, 1971, 1973, 1975-1976, and 1977.

To statistically define the persistence of anomalous periods, the autocorrelation function was used. This function describes the decay of the correlation coefficient as the data series is time shifted relative to itself an increasing number of months. The autocorrelation function of monthly Monterey sea level anomalies,

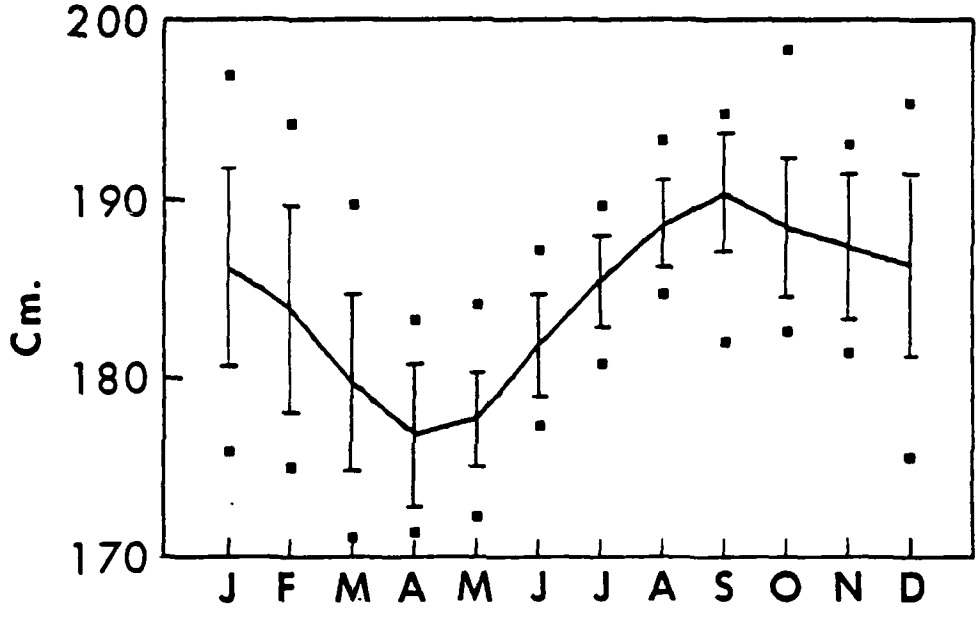


Figure 6. Annual Cycle of Mean Monthly Sea Level

(Standard Deviations Are Shown as Vertical Bars and Monthly Extremes as Dots)

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SEA LEVEL MONTEREY, CA BY MONTH

MONTH	VALUE	ANOMALY
196301	NO DATA	
2	NO DATA	
3	NO DATA	
4	NO DATA	
5	NO DATA	
6	NO DATA	
7	187.76	2.32
8	180.37	-.27
9	194.16	3.74
10	189.59	1.16
11	190.20	2.78
12	187.15	.81
196401	185.62	-.54
2	177.09	-8.79
3	175.87	-3.86
4	171.91	-4.94
5	172.21	-5.53
6	178.20	-3.84
7	180.75	-4.69
8	187.15	-1.49
9	189.28	-1.14
10	180.37	-.86
11	184.71	-2.78
12	185.01	-1.32
196501	187.76	1.59
2	184.71	.83
3	186.84	7.11
4	NO DATA	
5	176.17	-1.56
6	183.49	1.65
7	187.45	2.02
8	193.24	4.61
9	NO DATA	
10	NO DATA	
11	NO DATA	
12	NO DATA	
196601	NO DATA	
2	181.97	-1.91
3	177.09	-2.64
4	182.27	5.42
5	184.10	6.36
6	181.66	-.18
7	183.49	-1.94
8	190.50	1.87
9	187.76	-2.66
10	185.93	-2.50
11	189.89	2.48
12	185.62	-.71
196701	186.54	.37
2	182.58	-1.30
3	181.97	2.24
4	179.22	2.37
5	177.09	-.65
6	185.01	3.17
7	186.54	1.10
8	191.11	2.48
9	192.02	1.61
10	183.49	-4.94
11	190.50	3.09
12	188.28	1.73
196801	187.45	1.28
2	188.67	4.80
3	178.61	-1.12
4	175.87	-.98
5	177.39	-.35
6	177.39	-4.45
7	185.01	-.42
8	186.54	-2.10
9	189.28	-1.14
10	188.67	.24
11	185.62	-1.79
12	186.84	.51
196901	194.16	7.99
2	192.63	8.76
3	180.44	.71
4	179.83	2.98
5	181.97	4.23
6	184.40	2.56
7	186.37	2.93
8	190.50	1.87
9	194.77	4.35
10	192.02	3.60
11	192.94	5.53
12	191.72	5.38

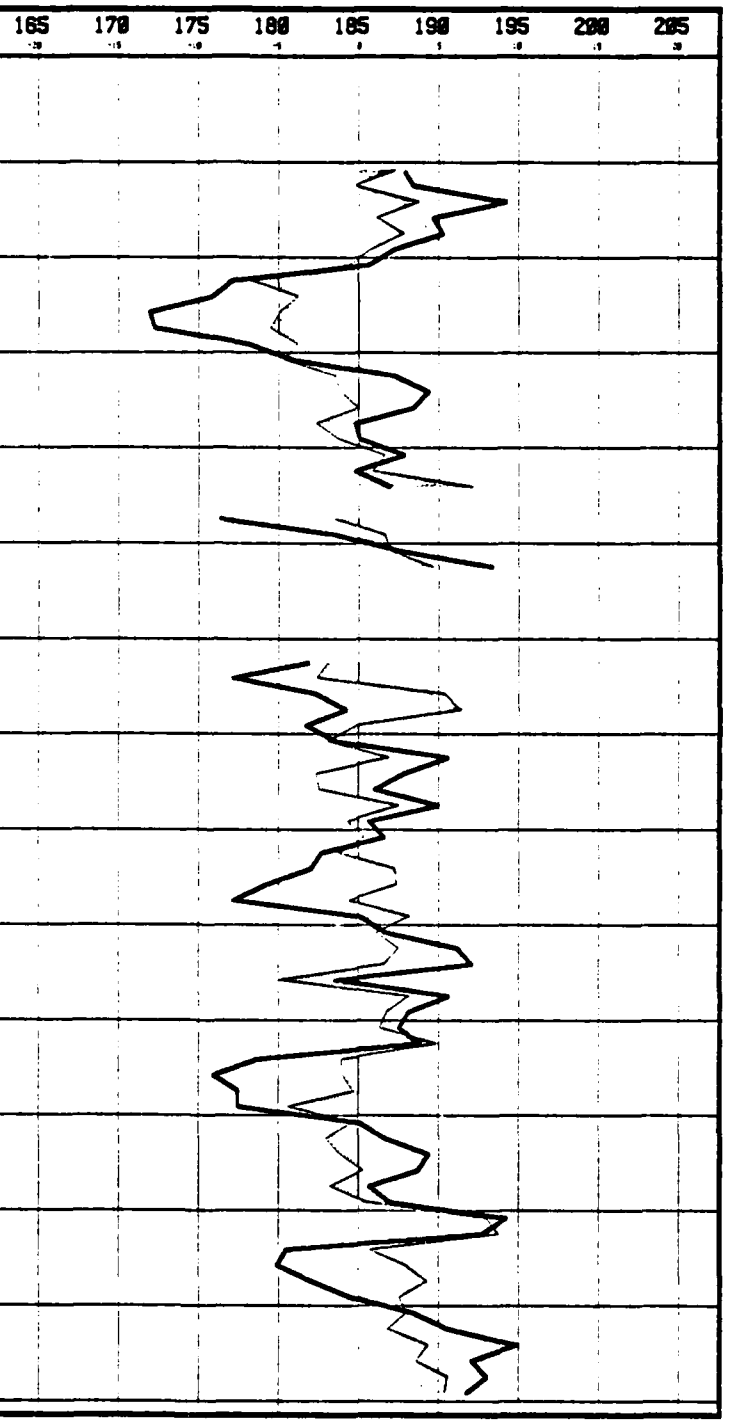


Figure 7A. Monterey Monthly Sea Level Means and Anomalies

(Monthly Means are Shown as Heavy Lines and Anomalies as Light Lines)

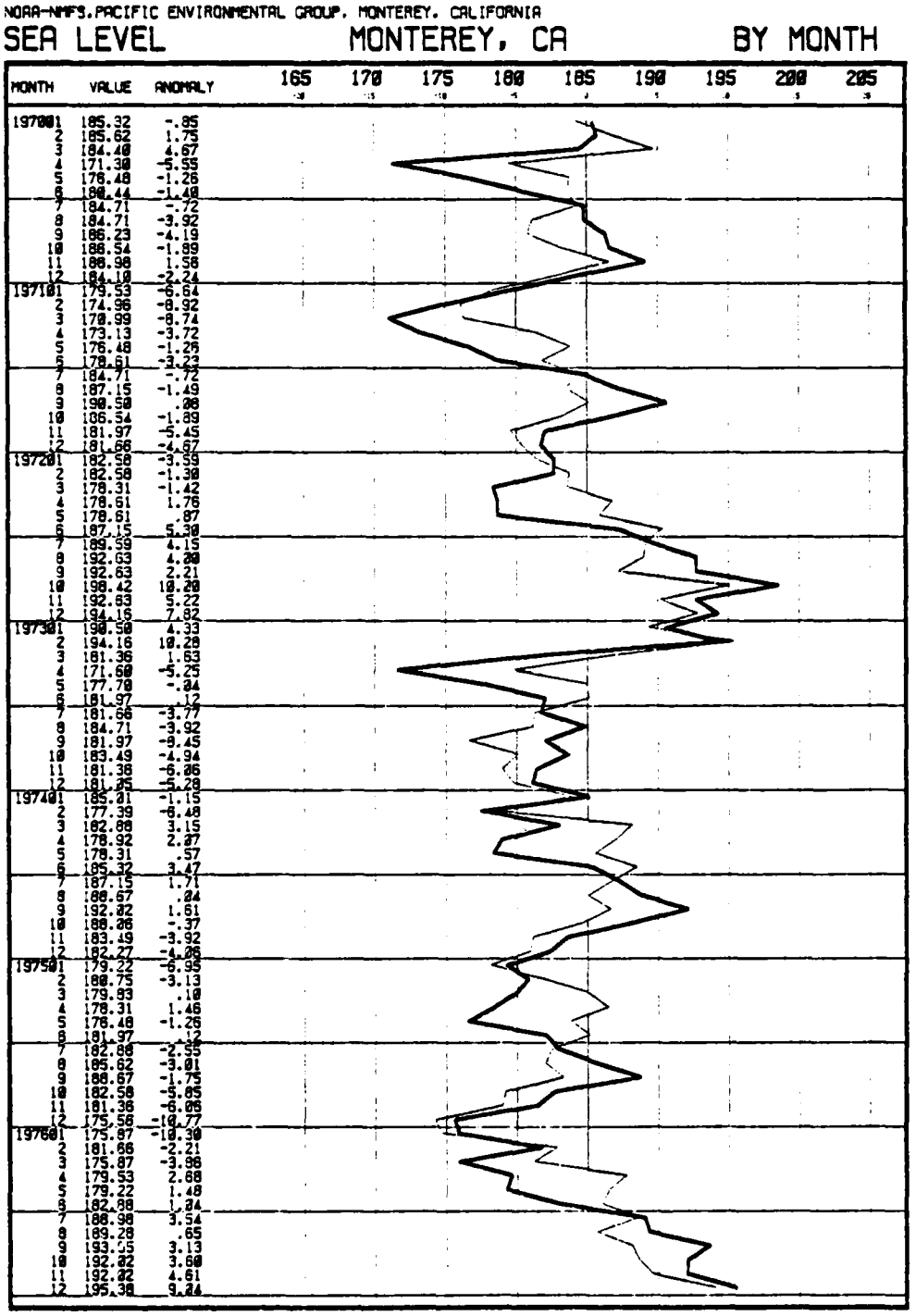

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA
SEA LEVEL
MONTEREY, CA
BY MONTH
MONTH VALUE ANOMALY
165 170 175 180 185 190 195 200 205

Figure 7B.

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SEA LEVEL MONTEREY. CA BY MONTH

MONTH	VALUE	ANOMALY
197701	189.89	3.72
2	179.83	-4.84
3	171.91	-7.82
4	172.21	-4.84
5	175.58	-2.17
6	181.97	.12
7	183.49	-1.91
8	188.67	.84
9	192.33	1.91
10	189.28	.85
11	185.93	-1.48
12	190.88	4.47
197801	198.90	10.73
2	193.55	9.57
3	189.59	9.80
4	183.18	8.34
5	178.31	.57
6	177.39	-4.45
7	184.40	-1.33
8	189.28	.85
9	191.11	.69
10	191.41	2.99
11	189.59	2.17
12	185.82	-.71

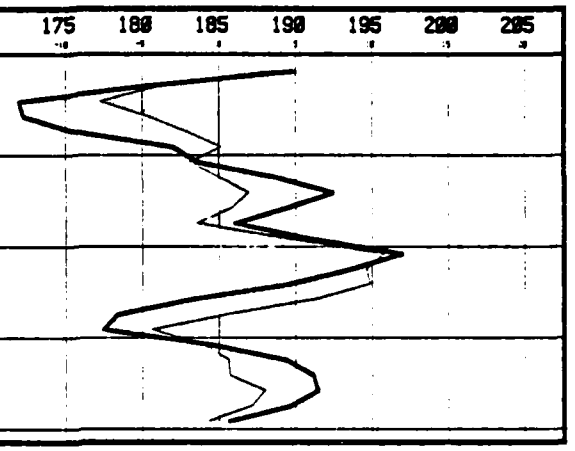


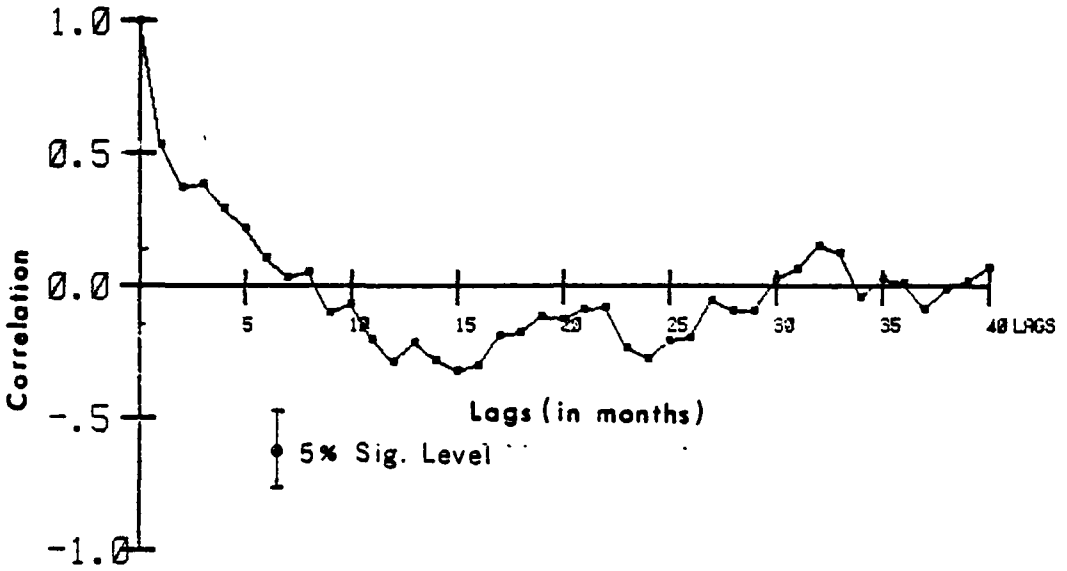
Figure 7C.

Figure 8, shows sea level anomalies to be correlated at the 5% level of significance for lags of up to 5 months, indicating that anomalies persist over a period of several months. The autocorrelation function of the sea level series appears to decay exponentially for the first 8 months or so, with significant negative autocorrelation coefficients occuring from lags of 11 to 18 and 23 to 26 months.

B. RELATION TO OTHER PACIFIC COAST TIDE STATIONS

We have seen that mean monthly sea level anomalies at Monterey tend to persist for about 5 months. The question naturally arises as to whether these anomalies are of local or regional geographic extent. To determine the spacial and temporal coherence between the monthly anomalies at Monterey and those observed at neighboring tide recording stations, monthly mean data were assembled for 15 tide stations along the Pacific coast ranging from Sitka, Alaska to Callao, Peru (Figure 9). These data were obtained from Dr. Klaus Wyrtki of the University of Hawaii and from the NOS. Stations selected for analysis were those having the best combination of the following characteristics: Representativeness of open ocean conditions, a long and continuous data record, a constant tidal reference datum during the time period of interest, and suitable spacing between station locations along the coast. For each station long-term monthly means were calculated from the available tide measurements for the period 1963 to 1978 and monthly sea level anomalies were derived, as for Monterey. These data are shown in Figures 10A-10C.

Variation in the month-to-month value of the anomaly may be seen from the figures to be greatest for stations north of Crescent City, showing the effects of energetic winter storms. Perhaps the most striking feature of the time series is the high visual correlation of anomalies along the coast. The periods of anomalously high sea level at Monterey during 1969, 1972-1973, 1976-1977, and 1978



AUTOCORRELATION ANALYSIS	
DATA POINTS	180
NUMBER OF LAGS	40
MEAN	-.262
ST DEVIATION	3.996
VARIANCE	15.972
SKEWNESS	-.030
KURTOSIS	3.170

Figure 8. Autocorrelation Function for Monthly Sea Level at Monterey

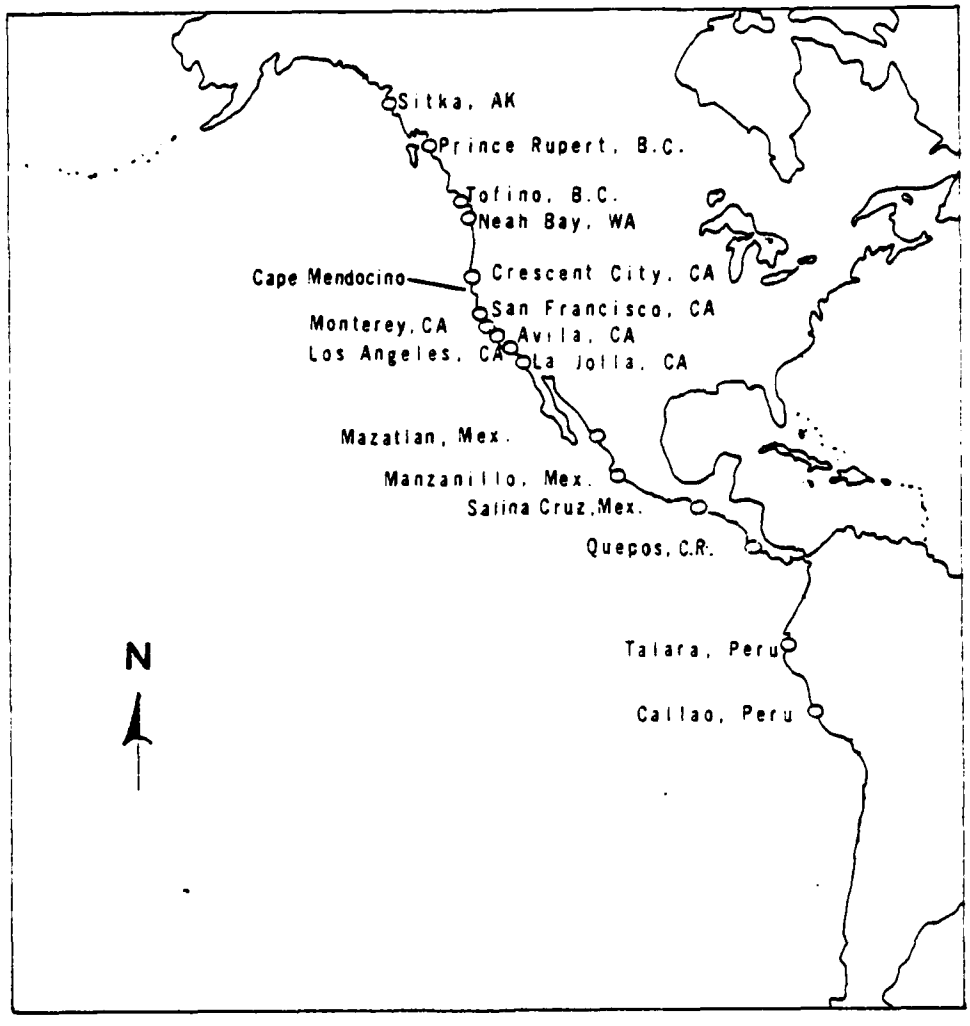


Figure 9. Selected Tide Stations Along the West Coasts of North and South America

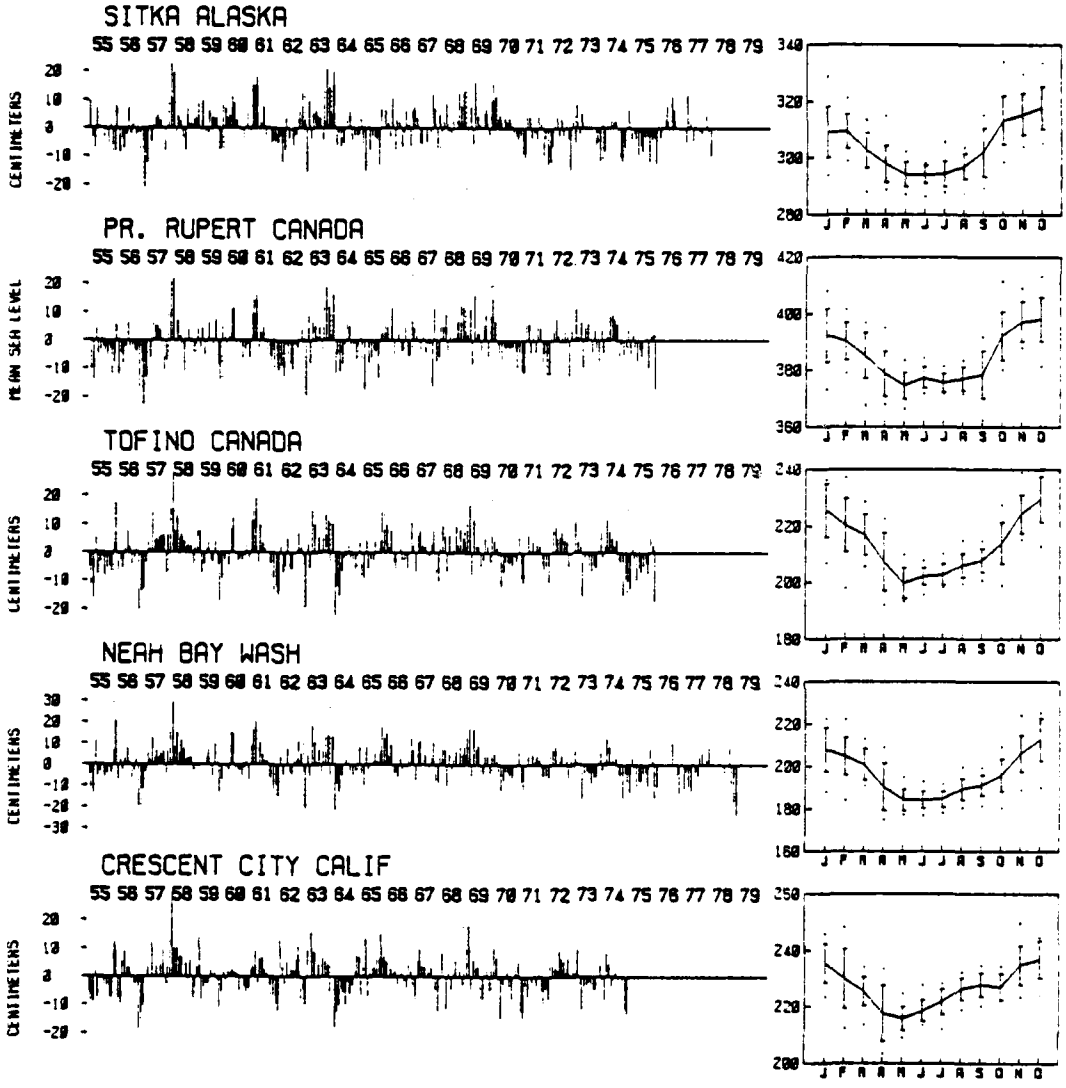


Figure 10A. Time-Series of Monthly Sea Level Anomalies for Selected West Coast Tide Stations

(Insets Show Mean Annual Cycle with Standard Deviations as Vertical Bars and Monthly Extremes as Dots)

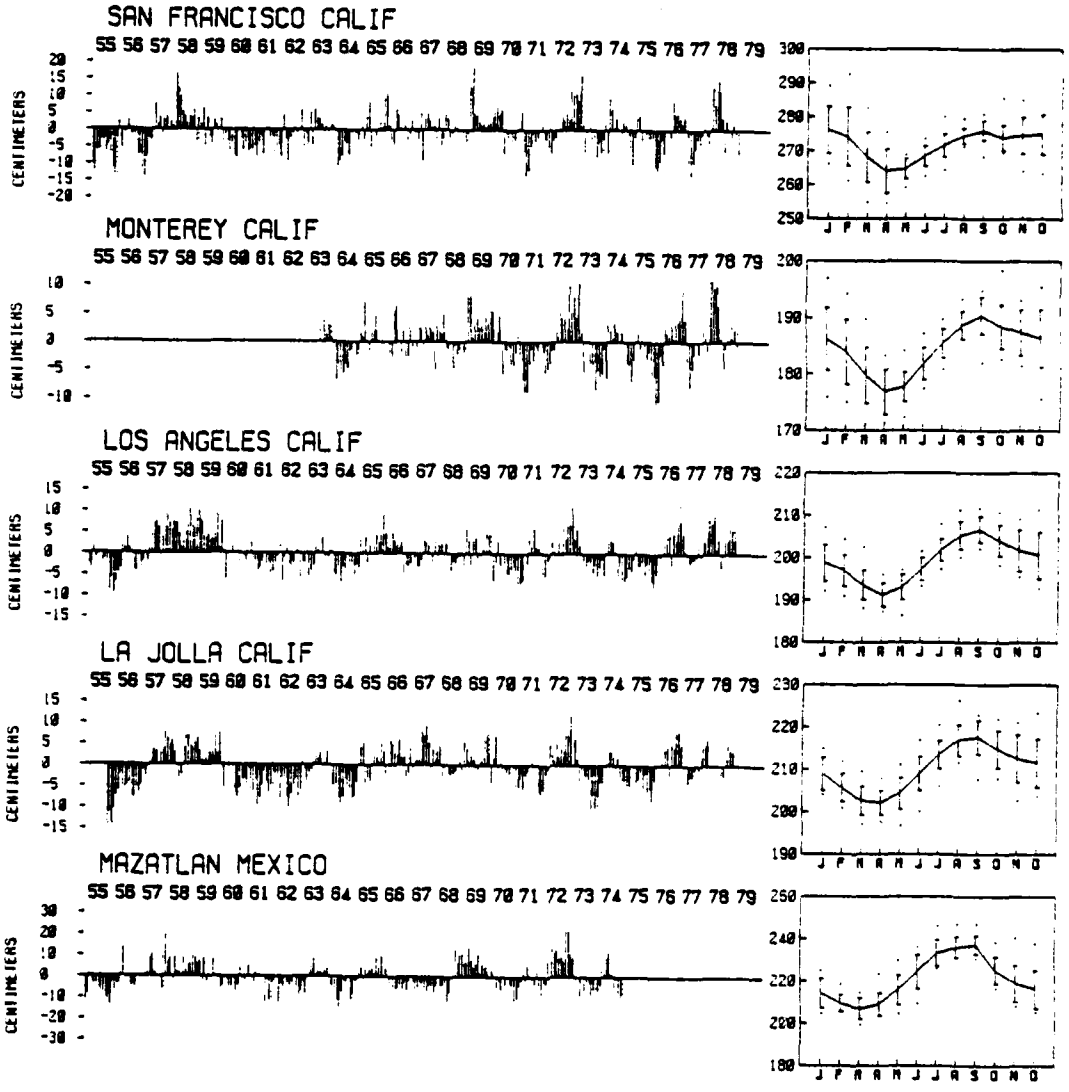

SAN FRANCISCO CALIF
MONTEREY CALIF
LOS ANGELES CALIF
LA JOLLA CALIF
MAZATLAN MEXICO
CENTIMETERS
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
J F M A M J J A S O N D

Figure 10B.

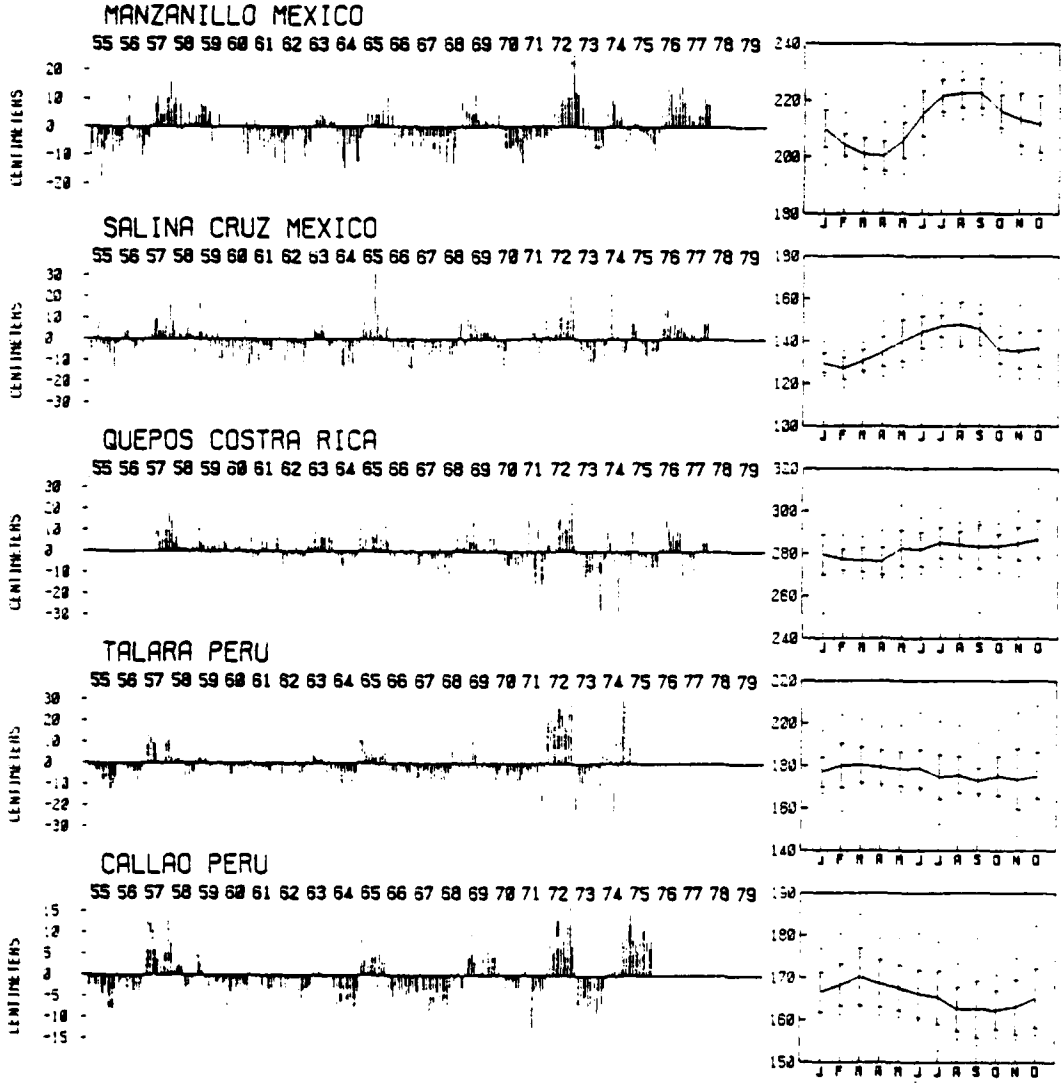

MANZANILLO MEXICO
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
SALINA CRUZ MEXICO
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
QUEPOS COSTRA RICA
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
TALARA PERU
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
CALLAO PERU
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
J F M A M J J A S O N D

Figure 10C.

were common to most stations where data are available. Similarly, the periods of anomalously low sea level seen at Monterey in 1964, 1970, 1971, 1973, 1975-1976, and 1977 occurred at most of the other stations. Also, the anomalies tend to reverse their sign more frequently at the northern stations than at the southern stations. This observation appears worthy of future study.

Correlations of the monthly sea level anomalies between stations were calculated using the BMDP8D statistical program (Dixon, 1975) and are tabulated in Table 1. The correlation of the selected tide stations relative to Monterey is shown graphically in Figure 11. Correlation of the Monterey anomalies is seen to be highest with San Francisco ($r = 0.85$) and lowest with Sitka ($r = 0.15$). It can also be seen that the correlation coefficient drops off more rapidly with distance to the north of Monterey than to the south.

Osmer and Huyer (1978) suggested the existence of two domains of coastal sea level fluctuations, with a boundary located south of San Francisco in winter and north of Crescent City in the spring and summer. The general location of their break-point is in agreement with the findings of Zee (1975), who suggested that sea level anomalies in his southern group of stations were related to non-seasonal vertical movement of the thermocline. That a strong gradient or boundary may exist between northern and southern stations is further suggested by Nelson (1977) who showed that the area off northern California near Cape Mendocino is one of marked change in the seasonal surface wind stress field. The mean seasonal wind stress field over the coastal ocean south of Cape Mendocino is alongshore (southward) all year while the stress field north of Cape Mendocino is strongly onshore in winter and alongshore (southward) in summer.

The alongcoast extent of sea level anomalies observed at Monterey was further examined in a time-distance domain. The monthly anomalies from the series of 15 coastal stations from Sitka, Alaska to Callao, Peru were plotted and

Table 1. Inter-Correlation of Monthly Sea Level Anomalies for Selected West Coast Tide Stations

	CAL	TAL	QPO	SCZ	MAN	MZN	LJLA	LA	MTRY	SF	CC	NEA	TF	PR	SKA
CAL	1.00														
TAL	.71	1.00													
QPO	.49	.57	1.00												
SCZ	.50	.44	.55	1 00											
MAN	.54	.49	.56	.72	1.00										
MZN	.64	.43	.55	.68	.90	1.00									
LJLA	.22	.26	.43	.42	.56	.51	1.00								
LA	.19	.27	.50	.48	.63	.63	.79	1.00							
MTRY	.23	.21	.43	.43	.53	.56	.75	.75	1.00						
SF	.25	.17	.36	.31	.41	.49	.57	.58	.84	1.00					
CC	.24	(.13)	.31	.33	.33	.37	.35	.38	.62	.67	1.00				
NEA	(.00)	(.05)	.26	.23	.21	.36	.15	.21	.32	.43	.75	1.00			
TF	(.02)	(.04)	.24	.26	.32	.41	.27	.36	.40	.47	.76	.94	1.00		
PR	(.03)	(.00)	.16	(.08)	.28	.37	.16	.24	.21	.27	.34	.67	.73	1.00	
SKA	(-.10)	(-.10)	.21	(.01)	(.12)	.22	.17	.15	(.15)	.17	.20	.49	.55	.81	1.00

Correlation coefficients enclosed in parentheses are not significant at the 5% level

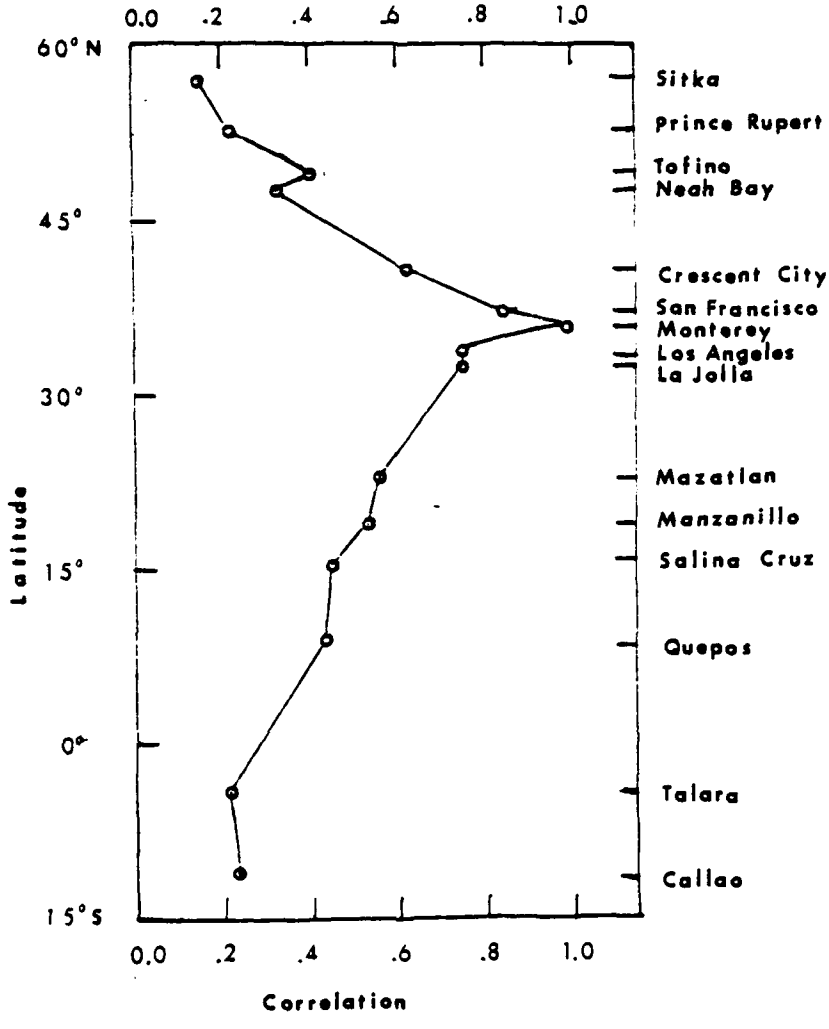


Figure 11. Correlation of Monthly Sea Level Anomalies at Selected West Coast Tide Stations Relative to Monterey

contoured at 5 cm intervals for the period 1963 to 1974 (Figures 12A-12D). Data for the years 1975 to 1978 were not available for several stations so plots for these years are not included. Anomalies are seen to fall into recognizable patterns which are coherent in both time and space. In Figure 12A, for example, large negative anomalies can be seen in January 1963 extending from Crescent City to Sitka and large positive anomalies in the same region occur in the subsequent fall and winter.

Larger anomalies and larger anomaly gradients occur northward of a boundary lying generally between Crescent City and Monterey. Anomalous events to the north of this boundary tend to occur simultaneously along the coast and are persistent for one or two months. Anomaly magnitudes and gradients are also generally larger southward of a second diffuse boundary zone lying approximately between Manzanillo and Quepos. Between these zones the anomaly field is relatively flat. Southward of the general boundary between Crescent City and Monterey sea level anomalies are of longer duration, as was noted earlier in reference to Figure 10.

A particularly interesting event is the anomalously high sea level during the period October 1972 through February 1973 between Callao and San Francisco (Figure 12D). This was a period of strong El Niño activity in the eastern tropical Pacific. During El Niño occurrences there is a rapid rise in sea level in the eastern tropical Pacific accompanied by a fall in sea level in the western Pacific (Wyrtki, 1977). In Figure 12D, for example, a peak anomaly of 25 cm was observed at Manzanillo in December 1972, where the occurrence of high sea levels preceeded those observed at more northern stations by a month or more. At Monterey, sea levels were higher than average during the winter of 1972-1973 (see also Figure 10). During the El Niño period, as shown in Appendix B, atmospheric pressures at Monterey were less than average and wind stress was negligible (except during February 1973 when anomalous southerly winds resulted in onshore transport of

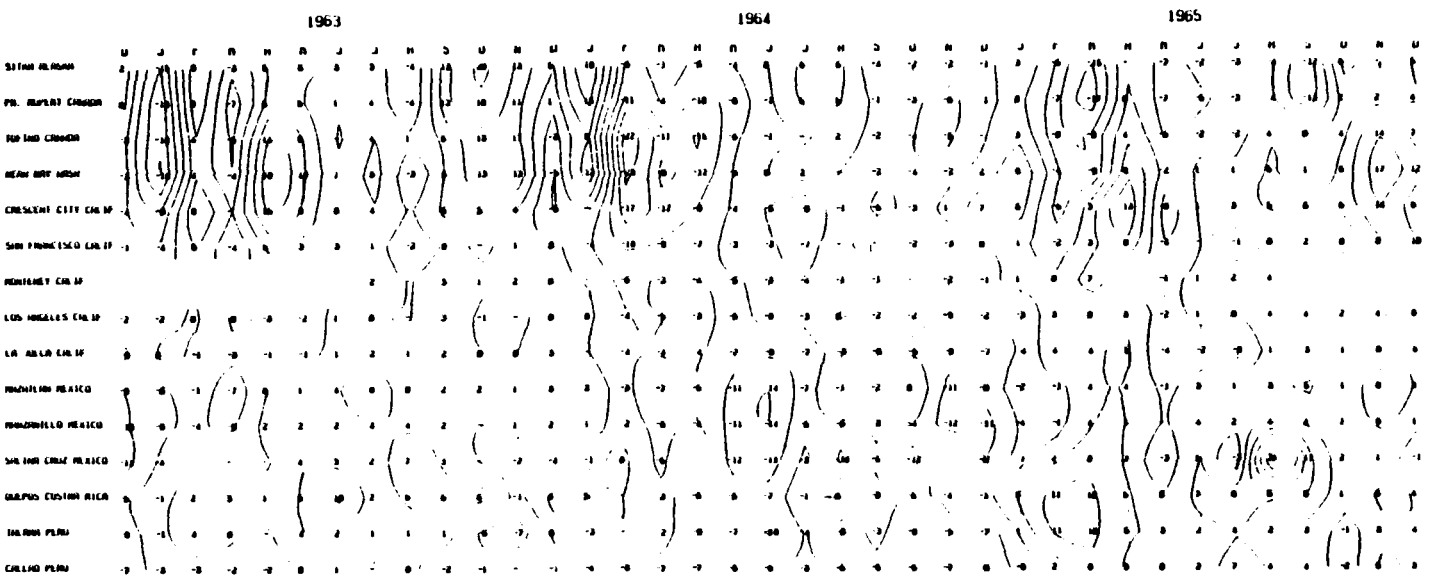


Figure 12A. Time-Distance Plot of Monthly Sea Level Anomalies at Selected West Coast Tide Stations

(Contour Interval is 5 cm)

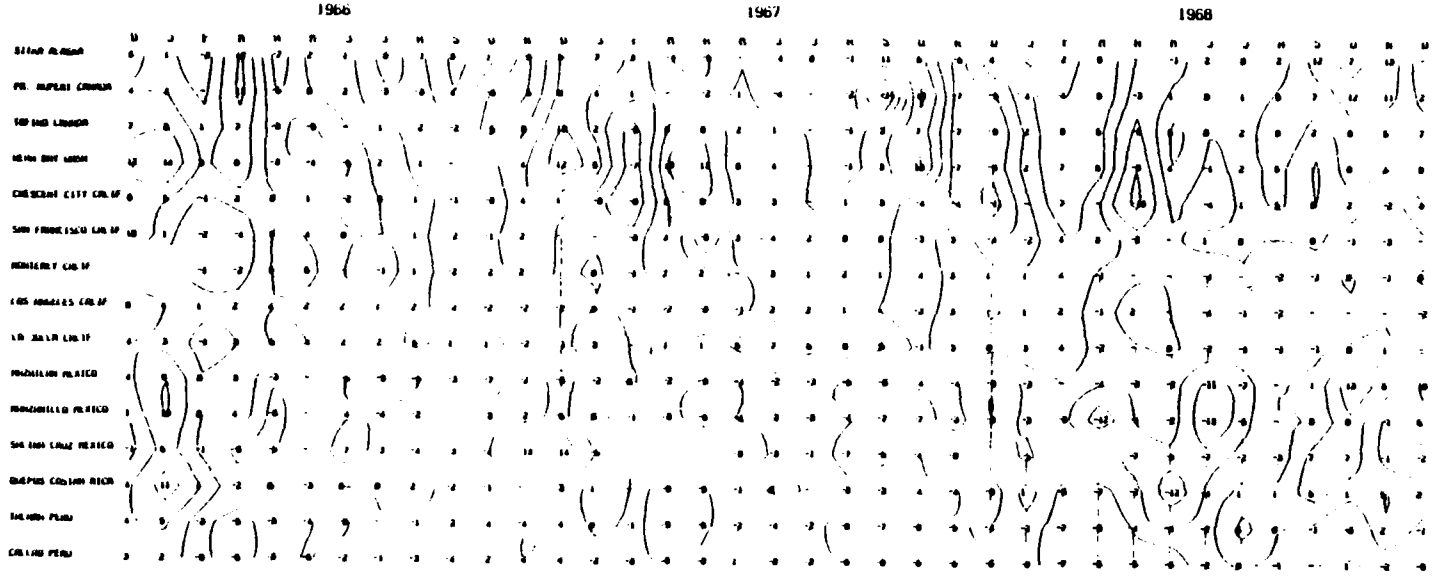


Figure 12B.

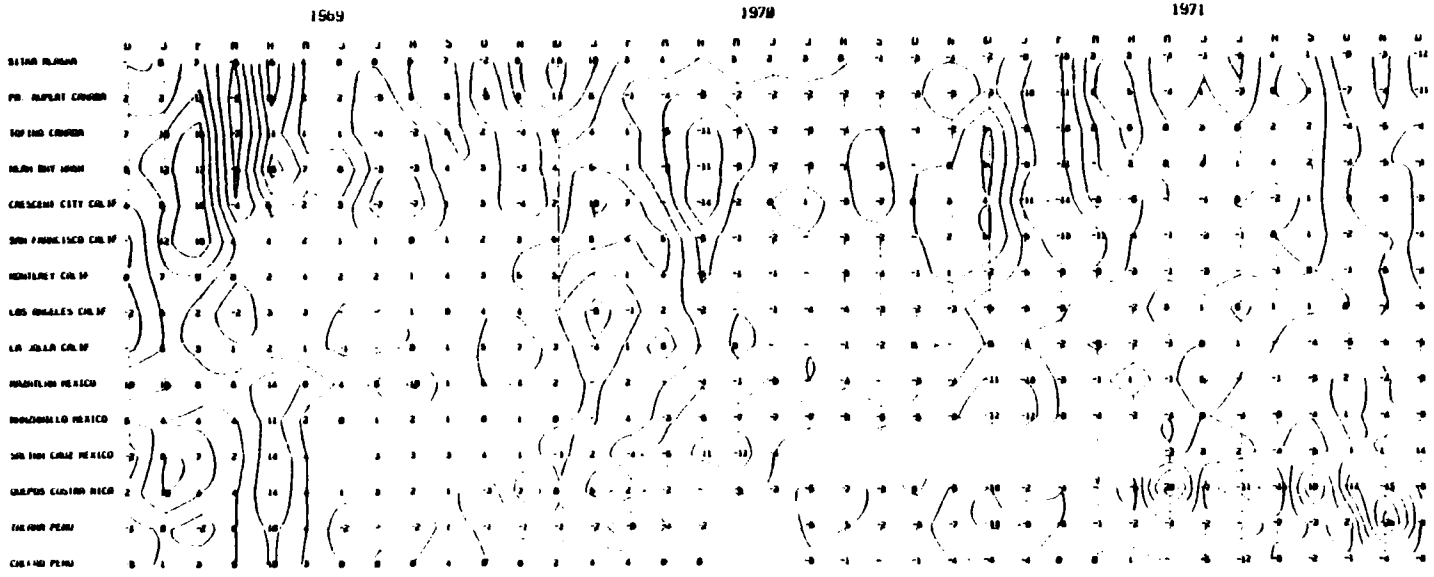


Figure 12C.

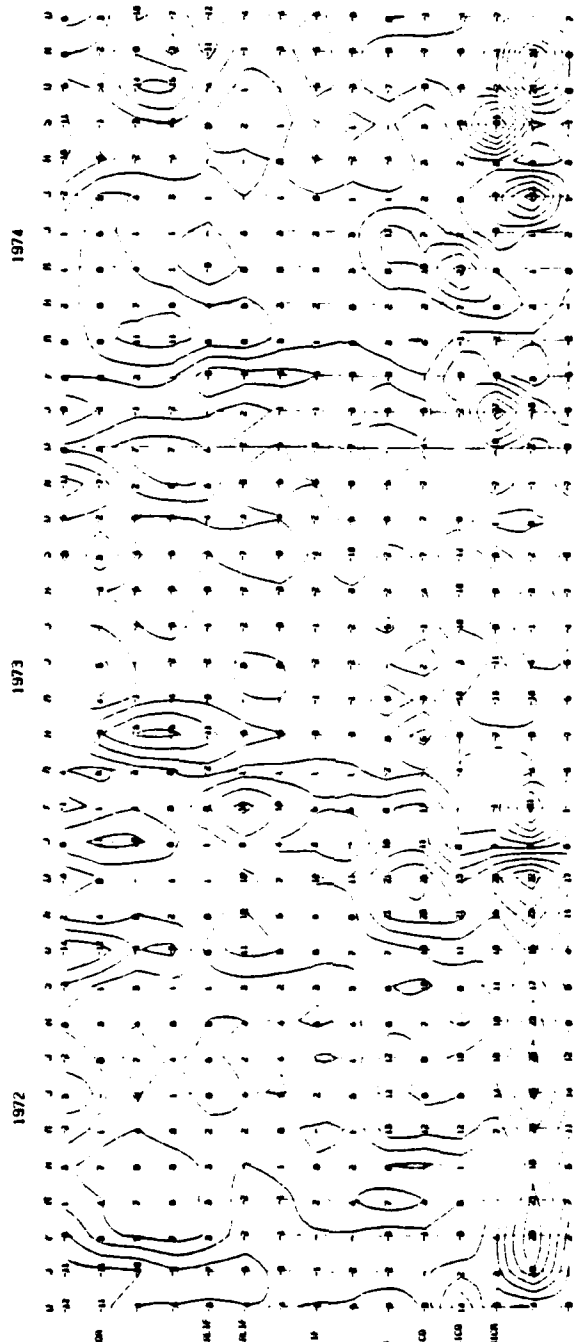


Figure 12D.

surface waters and downwelling). Sea surface temperatures were also anomalously high from August 1972 to March 1973.

In summary, monthly sea level anomalies at Monterey are related to large-scale influences rather than to strictly local events. Table 1 shows that the anomalies at Monterey are correlated, at the 5% level of significance, with anomalies recorded at stations from Prince Rupert, Canada to Callao, Peru, but are more closely related to events affecting sea levels in the group of stations from Crescent City to Quepos. Processes producing the El Niño phenomenon along the coast of Peru also apparently affect sea level at Monterey.

IV. CAUSES OF SEA LEVEL VARIATIONS AT MONTEREY

The effects of changes in atmospheric pressure, changes in water mass characteristics due to changes in alongcoast currents, and changes in average density of the water column on sea level are all interrelated. A change in the distribution of atmospheric pressure over the ocean surface will generally change the horizontal gradient of pressure, resulting in a change in the geostrophic and other wind components, and thus in wind stress. A change in wind stress will change the wind-driven current, redistribute the mass, and change the average density of the water column. Wind stress changes also alter wind-induced set-up or set-down against the coast. All of these processes combine to affect sea level.

So as to separate these effects, correlation, regression, and spectral analysis techniques were used. Fluctuations in sea level and other variables occur on various time scales. For this reason the following section is organized generally by time-sampling and specifically by analysis proceedures used. The procedures used were chosen as appropriate for the character of the data to be analyzed.

A. CORRELATION ANALYSIS

Mean monthly anomalies for the period 1963-1978 were calculated for the following oceanic and atmospheric variables: Surface atmospheric pressure, meridional wind stress, zonal wind stress, offshore Ekman transport, Sverdrup transport, SST, and salinity. These data are presented in Appendix B. Correlations between these variables and the monthly sea level anomalies at Monterey were calculated using the BMDP8D statistical program and the results given in Table 2. The correlation analysis measures the strength of the linear relationships between independent, random variables. However, the variables dealt with here are neither random nor independent so some care must be used in interpretation of the statistical results. In the following paragraphs each variable will be treated in turn and the results of the correlation analysis discussed.

Table 2. Inter-Correlation of Monthly Sea Level Anomalies and Monthly Anomalies of Various Ocean and Atmospheric Variables

	SL	ADJ SL	PRES	MERID WS	ZONAL WS	EKM TSPT	SVP TSPT	SAL	SST
SL	1.00								
ASL	.95	1.00							
PRES	-.69	-.46	1.00						
MWS	.43	.41	-.28	1.00					
ZWS	(-.13)	-.18	(-.03)	-.47	1.00				
EKM TSPT	-.42	-.41	.25	-.99	.58	1.00			
SVP TSPT	(.00)	(-.06)	-.18	-.32	.14	.32	1.00		
SAL	-.35	-.30	.29	-.31	(.07)	.30	.20	1.00	
SST	.61	.64	-.28	.37	-.17	-.37	(-.05)	-.37	1.00

Correlation coefficients enclosed in parentheses are not significant at the 5% level

The effect on sea level of changes in atmospheric pressure over the oceans has been examined by a number of authors (Patullo, et al., 1955; Saur, 1962; Roden, 1960). An increase (decrease) in atmospheric pressure results in a decrease (increase) in sea level. These effects can be quite large in some areas, particularly in the Gulf of Alaska where winter storms are intense or along the Gulf or Atlantic coasts of the United States during the passage of hurricanes.

The isostatic contribution of atmospheric pressure variations to variations in sea level is computed from the hydrostatic equation, $p = -dgh$ where p is the change in atmospheric pressure in millibars (mb), d is the density of water in g/cm^3, g is the acceleration of gravity in cm/sec^2, and h is the change in sea level in cm. Applying this equation to sea water of density 1.025 g/cm^3 and using 980.7 cm/sec^2 as the acceleration of gravity, we find that an increase in atmospheric pressure of 1 mb will result in a 0.995 cm depression of sea level.

The seasonal range of monthly mean atmospheric pressure at Monterey during the period 1963 to 1978 was 7.3 mb, but pressure changes several times greater than this are not uncommon during the passage of intense winter storms. Thus, the effect of atmospheric pressure is expected to account for a significant portion of sea level variability near Monterey.

Maixner (1973) examined hourly data recorded from the Monterey tide gage during the year 1971 and concluded that hourly sea level responds to pressure changes in an approximately hydrostatic manner. The coefficient of correlation between monthly mean sea level anomalies and pressure anomalies, based on 180 months of simultaneous data from the period July 1963 through December 1978, was found in the present study to be -0.69 (Table 2). The relatively large negative correlation coefficient indicates that hydrostatic equilibrium is somewhat applicable to monthly statistics.

It was considered desirable to remove the static effects of atmospheric pressure from the monthly sea level data so that the influence of other variables on sea level could more readily be examined. To accomplish this, monthly mean sea levels were adjusted for monthly pressure effects by increasing (decreasing) sea level 1.00 cm for every 1.00 mb increase (decrease) of atmospheric pressure. The use of the more accurate value of 0.995 was not warrented in this study. The magnitude of the pressure correction was determined by subtracting the long term mean pressure for the period January 1963 through December 1978 (1016.85 mb) from the monthly mean atmospheric pressures. Mean monthly sea levels and sea level anomalies from which the hydrostatic effect associated with monthly pressure anomalies have been removed are referred to in this study as adjusted sea levels. The time series of adjusted and unadjusted sea level anomalies and long-term means for the period 1963 through 1978 are shown in Figure 13.

In general, the contribution of atmospheric pressure is seen in the time series to be small compared with the observed departures of sea level. In most months the pressure correction is opposite in sign to the sea level anomaly and causes a reduction in the sea level variability. The greatest differences occur in winter months. The effect of the subtraction of static pressure on the seasonal sea level shown in the figure is to reduce the range of the monthly values, and to a very small extent the seasonal range, but also to shift the time of highest sea level from September to December. Pressure effects account for a portion of the sea level variability but significant non-barometric residuals remain, indicating the effects of dynamic as well as static processes.

The effects of wind stress on sea level are twofold; the direct elevation or depression of water by winds normal to the coast and the sea surface slopes created by offshore or onshore Ekman transport produced by winds parallel to the coast. The direct piling up of water is commonly observed in areas with wide,

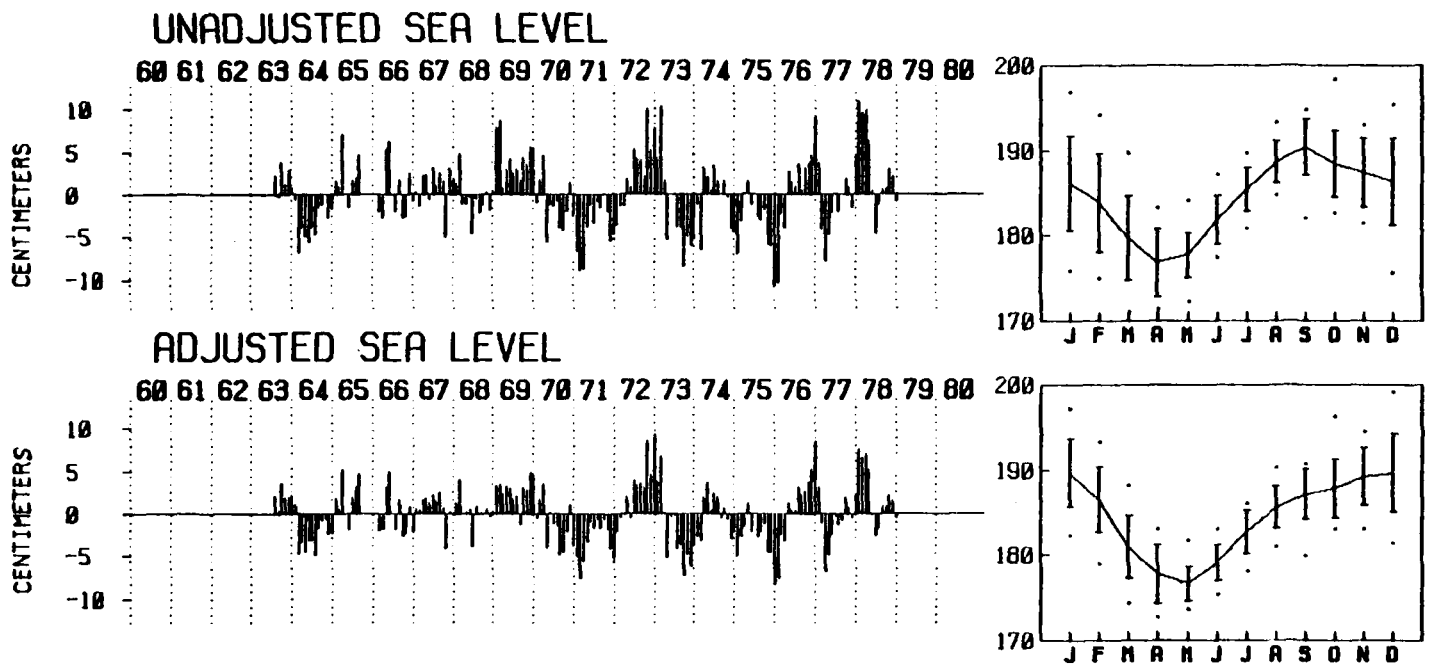


Figure 13. Adjusted and Unadjusted Monthly Mean Sea Level at Monterey

(Insets Show Mean Annual Cycle with Standard Deviations as Vertical Bars and Extremes as Dots)

shallow continental shelves or long, narrow embayments. The magnitude of this effect is dependent on basin configuration, surface wind velocity, and the depth of water. The shelf in the Monterey area is quite narrow with deep water located close inshore so that the effects of wind set-up are small. Defant (1961) showed, for example, that a constant 10 m/s wind blowing over a basin 50 m deep would produce a sea surface slope of 6.6 cm/100 km. The 50 m contour near Monterey is less than 1.6 km offshore (Figure 1), and the magnitude of the effects of direct piling of water by the wind are believed to be less than the range of error in tide measurements. In addition, monthly anomalies of zonal (east or west) wind stress were found not to be significantly correlated with monthly sea level anomalies at the 5% level of significance (Table 2). Accordingly, the effects of the piling up or depression of sea level by wind stress are neglected in this analysis.

The second effect of wind stress is that of sea surface slopes produced by offshore or onshore Ekman transport due to winds parallel to the coast. According to conventional Ekman transport theory, net transport is directed 90° to the right of the wind in the northern hemisphere. In this study, offshore/onshore Ekman transport was found to be significantly correlated with sea level ($r = -0.42$ in Table 2). The inverse correlation indicates that offshore transport results in decreased sea level and onshore transport in increased sea level. Meridional wind stress is also significantly correlated with sea level ($r = 0.42$), as expected.

Sea surface temperature ($r = 0.61$) and surface salinity ($r = -0.35$) are both significantly correlated with monthly sea-level anomalies. The signs of the correlations indicate that increases in SST are associated with increased sea levels and increased salinities are associated with decreased sea levels. These relationships are consistent with basic considerations of sea water density changes.

Monthly anomalies of Sverdrup transport were found not to be significantly correlated with monthly sea level anomalies at the 5% level of significance.

B. REGRESSION ANALYSIS

We have seen that the monthly sea level anomalies are significantly correlated with atmospheric pressure, meridional windstress, offshore Ekman transport, SST, and surface salinity. To further quantify these relationships, a multiple regression analysis was performed. The eight variables input into the BMDP2R stepwise multiple regression program (Dixon, 1975) were monthly anomalies of sea level, atmospheric pressure, meridional wind stress, zonal wind stress, offshore Ekman transport, Sverdrup transport, surface salinity, and surface temperature.

The results of the regression analysis, presented in Table 3 (upper part), show that surface atmospheric pressure is the major predictor of sea level, with SST and meridional windstress as second and third predictors. The remaining variables were neglible and their coefficients are not included in the table. Together, these three variables explain over 68% of the variance of the monthly sea level anomalies. The regression formula shown in the table indicates that the response of sea level to changes in atmospheric pressure is -1.67 cm/mb whereas a purely hydrostatic response would be -1.00 cm/mb. This higher than theoretical pressure response is in agreement with the results of Saur (1962) and Roden (1960) who analyzed monthly tide data at stations north and south of Monterey.

Because of the significant seasonal changes in the oceanic and atmospheric regimes near Monterey we might expect to observe seasonal changes in the processes affecting sea level. To define these seasonal changes the ocean and atmospheric data contained in Appendix B were analyzed by multiple regression during two periods, the Davidson Current and the upwelling seasons.

Sea level changes centered on the Davidson current period were analyzed using 5 months of data (October through February) for the years 1963 to 1978. As described earlier, this is a period of weak northerly winds, northward coastal

Table 3. Results of Multiple Regression Analysis

A. Dynamic Height Not Included

Step No.	Variable	Explained Variance	Increase In Explained Variance
1	PRES	0.48	0.48
2	SST	0.67	0.19
3	MWS	0.68	0.01

SEA LEVEL (cm) = 0.15 - 1.67 PRES (mb) + 2.09 SST (°C) + 3.34 MWS (dynes/cm^2)

B. Dynamic Height Included

Step No.	Variable	Explained Variance	Increase In Explained Variance
1	PRES	0.42	0.42
2	SST	0.66	0.24
3	DYNHT	0.72	0.06
4	MWS	0.74	0.02

SEA LEVEL (cm) = -0.32 - 1.43 PRES (mb) + 1.72 SST (°C) + 0.16 DYNHT (dyn cm) + 4.88 MWS (dynes/cm^2)

current flow, and frequent cyclonic storm activity. The results of multiple regression analysis, shown in Table 4, indicate that atmospheric pressure and SST are major predictors of sea level during this period, explaining over 71% of the variance of monthly sea level anomalies.

The second period analyzed was centered on the upwelling season and covered the months April through August during the years 1964 through 1978. The upwelling season is a period of northerly winds, offshore transport of coastal surface waters, and southward California Current flow. The results of multiple regression analysis indicate that during this period monthly anomalies of atmospheric pressure, SST, and meridional windstress account for 58% of the variability of monthly sea level (Table 4).

Thus, some seasonal change in the processes affecting sea level is indicated, with monthly atmospheric pressure and SST anomalies accounting for most of the monthly sea level variability in both the Davidson Current and upwelling seasons, and meridional windstress explaining an additional portion of the sea level variability during the upwelling season.

Table 4. Results of Multiple Regression Analysis By Season

A. Davidson Current Season

Step No.	Variable	Explained Variance	Increase In Explained Variance
1	PRES	0.49	0.49
2	SST	0.71	0.22

SEA LEVEL (cm) = 0.07 - 1.69 PRES (mb) + 2.49 SST (°C)

B. Upwelling Season

Step No.	Variance	Explained Variance	Increase In Explained Variance
1	PRES	0.29	0.29
2	SST	0.53	0.24
3	MWS	0.58	0.05

SEA LEVEL (cm) = 0.58 - 1.43 PRES (mb) + 2.27 SST (°C) + 3.83 MWS ($dynes/cm^2$)

C. SPECTRUM ANALYSIS

It has just been shown that much of the variance of monthly sea level anomalies can be explained by monthly anomalies of atmospheric pressure, SST, and meridional windstress. However, important variations in these processes occur on time scales shorter than a month. To determine how the variance of sea level is distributed with frequency over time-periods of days to weeks, auto and cross spectra were calculated for six-hourly observations of sea level, atmospheric pressure, and the meridional component of wind stress.

Surface atmospheric pressure and meridional wind stress were calculated as described previously on a six-hourly basis for the period January 1, 1967 through August 31, 1976 for a point approximately 14 km west of the Monterey tide station (Figure 1). Hourly sea level data for the same time period were low-pass filtered to remove the diurnal, semi-diurnal, and other short-term tidal components and were sub-sampled at six-hourly intervals; a complete description of the low-pass filter is given by Godin (1966). These data series were then detrended by subtracting their 30-day running mean to produce a band-passed series. The response function for the 30-day running mean is shown in Figure 14.

Surface atmospheric pressure, wind stress, and adjusted and unadjusted sea level data were analyzed during the winter storm period (November 1 to March 8) and the upwelling period (April 1 to August 8) for the years 1967 to 1976. A fast fourier transform spectrum analysis with a triangular data window was used and the seasonal spectra were averaged over all available years. The frequency bandwidth is 0.04 cpd and the number of degrees of freedom is 90 for the winter season and 100 for the upwelling season.

The spectral relationships between sea level and atmospheric pressure are shown in Figures 15A and 15B and will be discussed first. In the low frequency region, the winter spectra are more energetic than the upwelling period spectra,

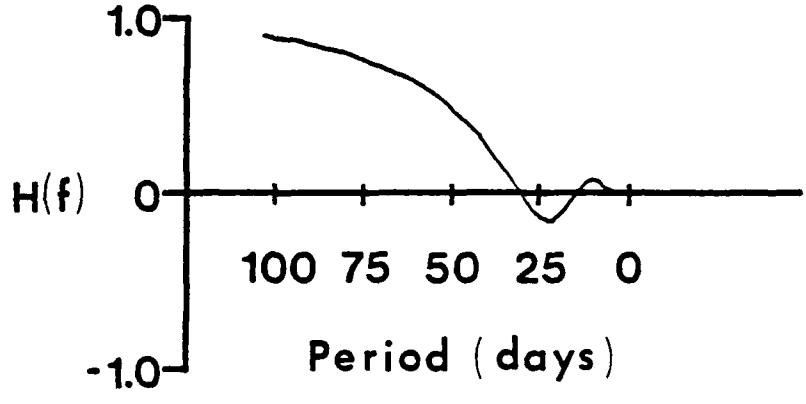


Figure 14. Response Function for 30-day Running Mean Filter

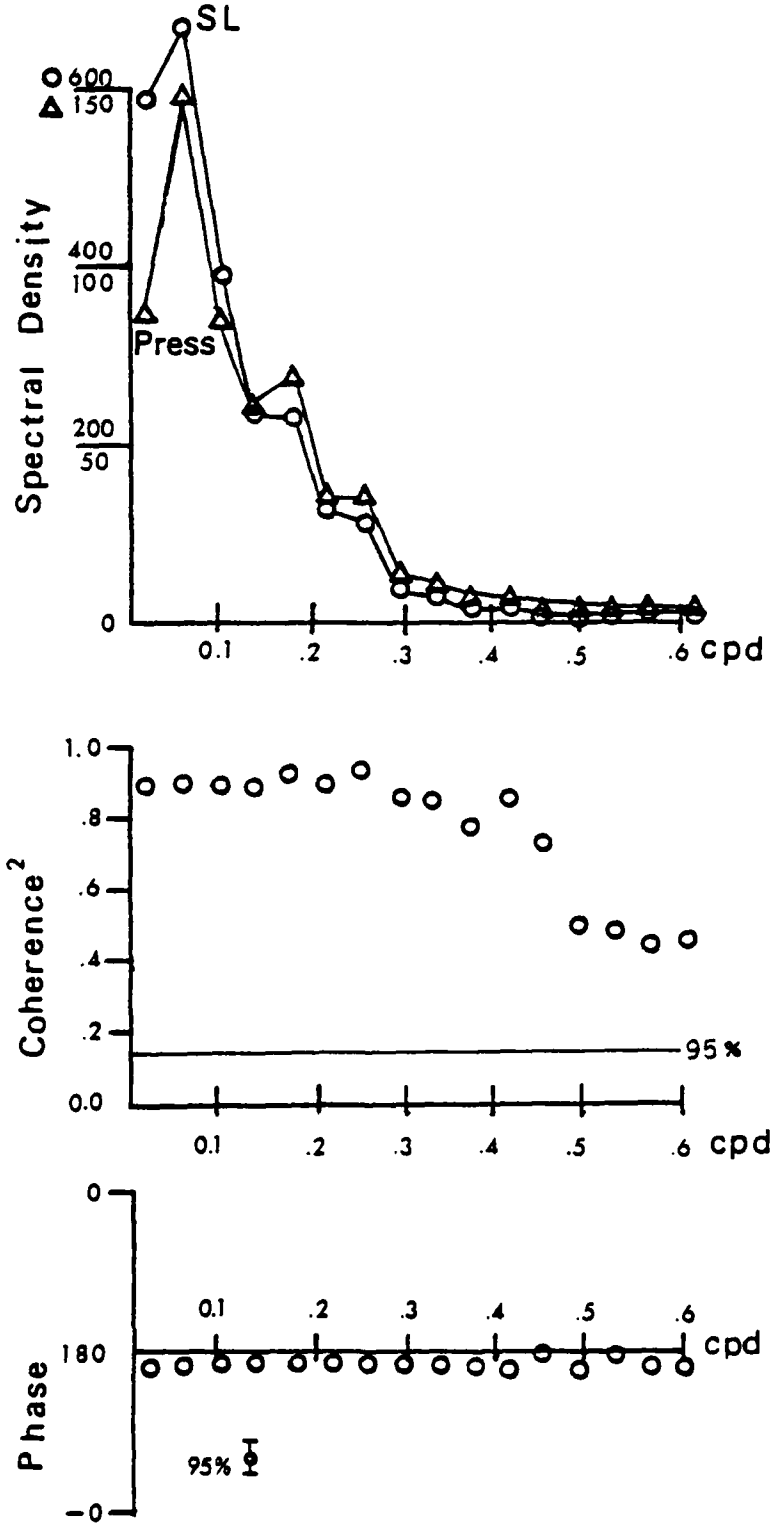


Figure 15A. Spectra of Six-Hourly Atmospheric Pressure and Unadjusted Sea Level (Winter Season)

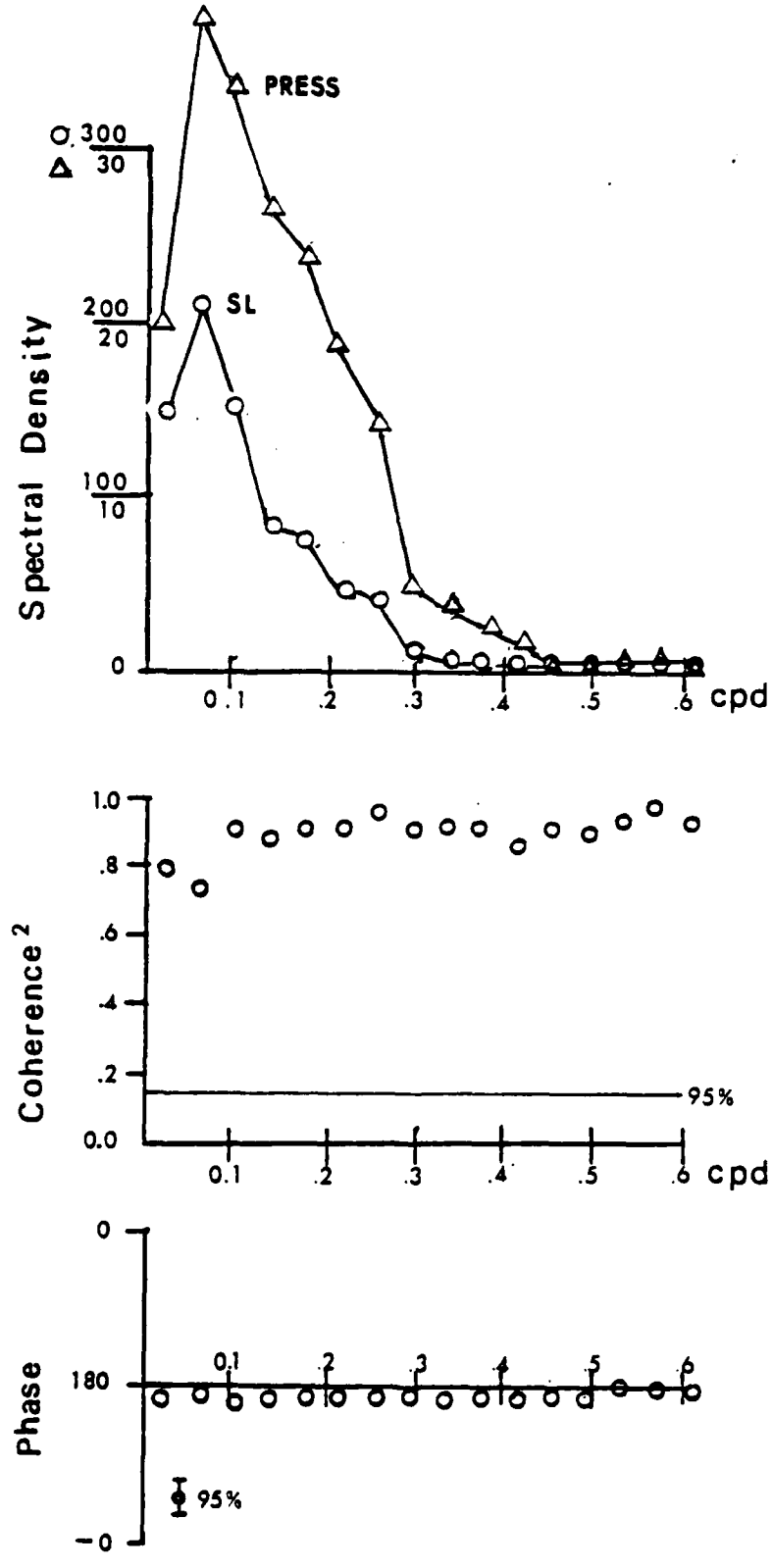


Figure 15B. Spectra of Six-Hourly Atmospheric Pressure and Unadjusted Sea Level (Upwelling Season)

indicating the effects of intense winter storm events. The largest sea level and pressure fluctuations occurred in the 12 to 24 day frequency band (on the event or storm time-scale). It is difficult to say much about the spectral peak observed at 16 days. The analysis scheme used in this section was designed to focus on variations with periods of 2 to 10 days but did not reveal any significant spectral peaks in this region. A recoloring of the spectrum suggests the possibility of some leakage from the negative filter side-lobe seen in Figure 14 into the frequency band centered on 0.0625 cpd.

The coherence (squared) between sea level and atmospheric pressure was found to be significant and independent of frequency in the upwelling period (Figure 15B) but decreased in magnitude for periods shorter than two days in the winter series (Figure 15A). The constant 180° phase between these two data sets indicates the inverse response between atmospheric pressure and sea level as expected from the hydrostatic equation.

To remove pressure effects, in order to better examine the relationship of wind stress and sea level, the low-passed six-hourly sea level series was adjusted for atmospheric pressure effects and detrended in the manner described previously. The six-hourly adjusted sea level and meridional wind stress series were then analyzed and auto and cross spectra calculated (Figure 16A, 16B). The meridional wind stress also had a concentration of energy at low frequencies with large variations occurring in the 12 to 24 day frequency band, and the winter power spectra containing more energy than those of the upwelling season. Coherence between adjusted sea level and meridional wind stress is generally low. The phase functions provide little information because of the low coherence.

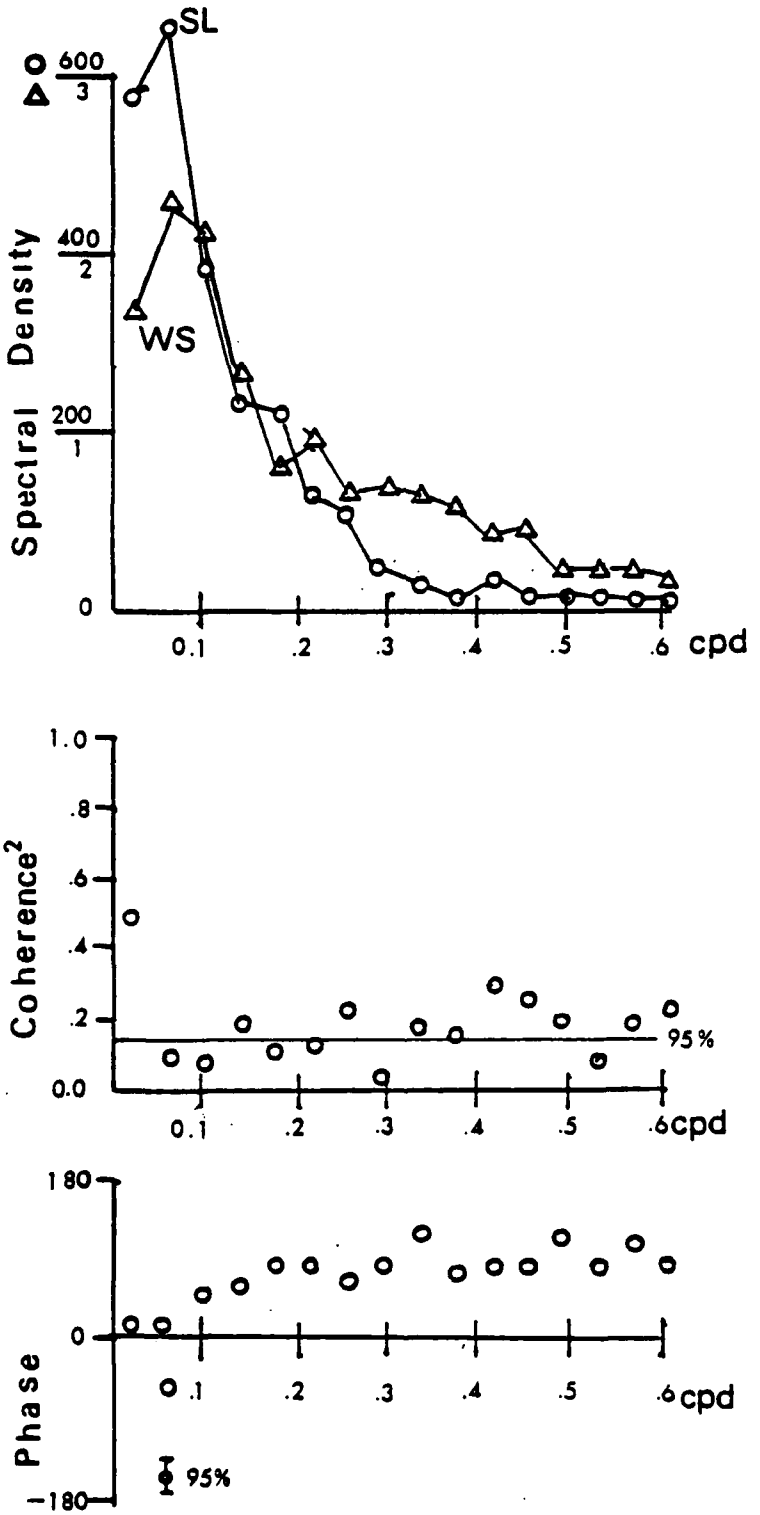


Figure 16A. Spectra of Six-Hourly Meridional Wind Stress and Adjusted Sea Level (Winter Season)

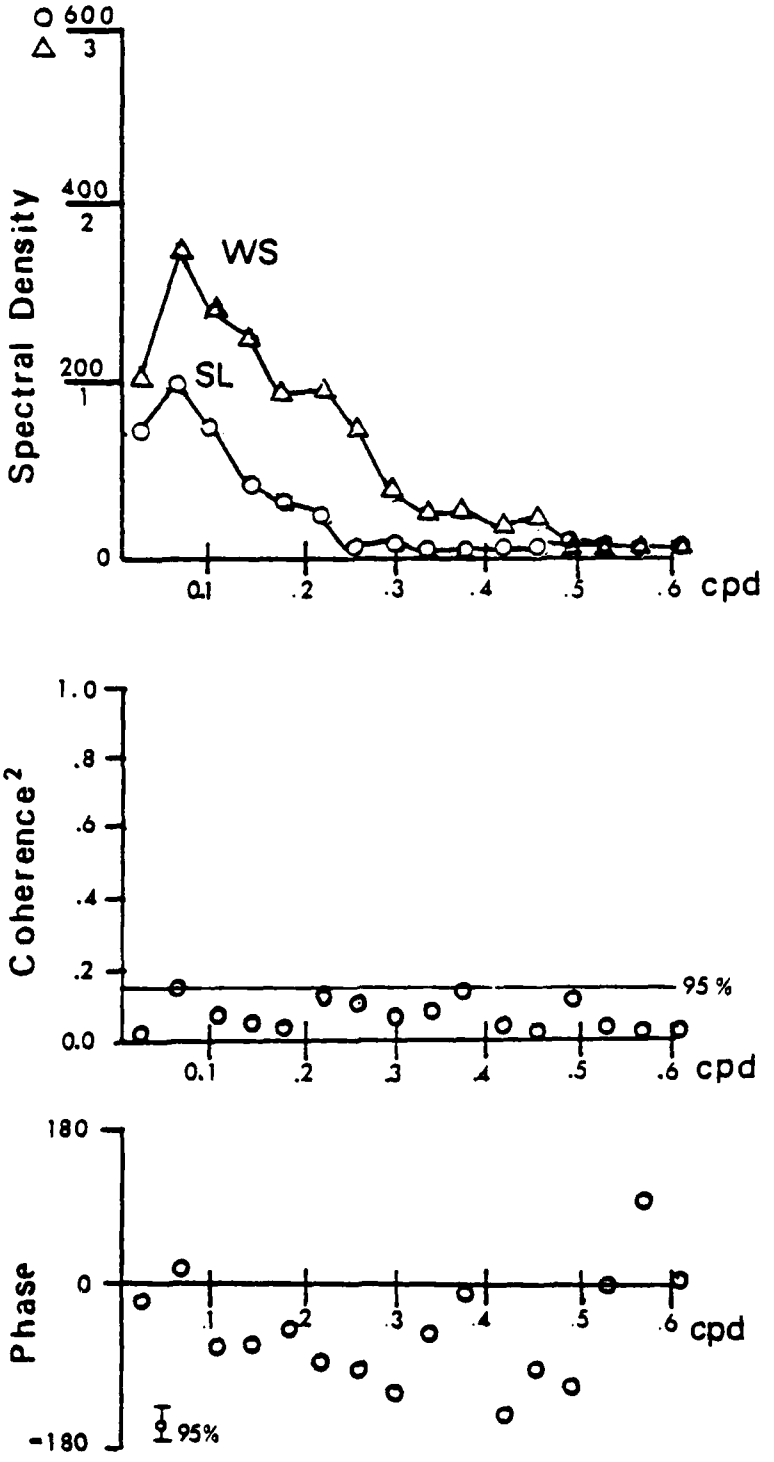


Figure 16B. Spectra of Six-Hourly Meridional Wind Stress and Adjusted Sea Level (Upwelling Season)

D. DYNAMIC HEIGHT

Sea surface temperature and salinity, examined earlier using multi-variable correlation and regression techniques, are only surface samples but may be indicative of the subsurface density distribution. Dynamic height calculations, however, provide a direct measure of the subsurface density field and its changes, and therefore are a measure of changes in ocean circulation. Mean monthly dynamic height anomalies and long-term means were calculated, as described earlier, for a site in mid-Monterey Bay for the period 1968 through 1977. A multiple regression analysis was run which included monthly dynamic height data with that of the eight ocean and atmospheric variables described previously. The results of this analysis, shown in the lower part of Table 3, indicate that inclusion of monthly dynamic height anomalies increased the explained variance of monthly sea level anomalies from 69% to 74%.

The relationship between sea level and dynamic height was further examined in a seasonal sense. Figure 17 shows the mean seasonal cycle of dynamic height and adjusted sea level. There is good agreement in both phase and amplitude of these curves. The observed seasonal cycle for dynamic height is noisy as a result of limited sampling (only 5 hydrocasts in January but up to 18 in other months; Bretschneider and McLain, 1979). The figure shows that both sea level and dynamic height near Monterey are highest in winter and lowest in spring.

Reid and Mantyla (1976), using the La Jolla tide data as an example, showed that south of 40° N in the eastern North Pacific Ocean sea levels are typically highest in late summer and early fall and lowest in late winter as a result of the annual solar heating cycle. North of 40° N, however, sea levels are highest in winter and lowest in summer; this pattern cannot be explained by the steric response to seasonal heating and cooling. Using Sturges' (1974) data from Neah Bay, Reid and Mantyla further demonstrated that maximum sea levels occur in

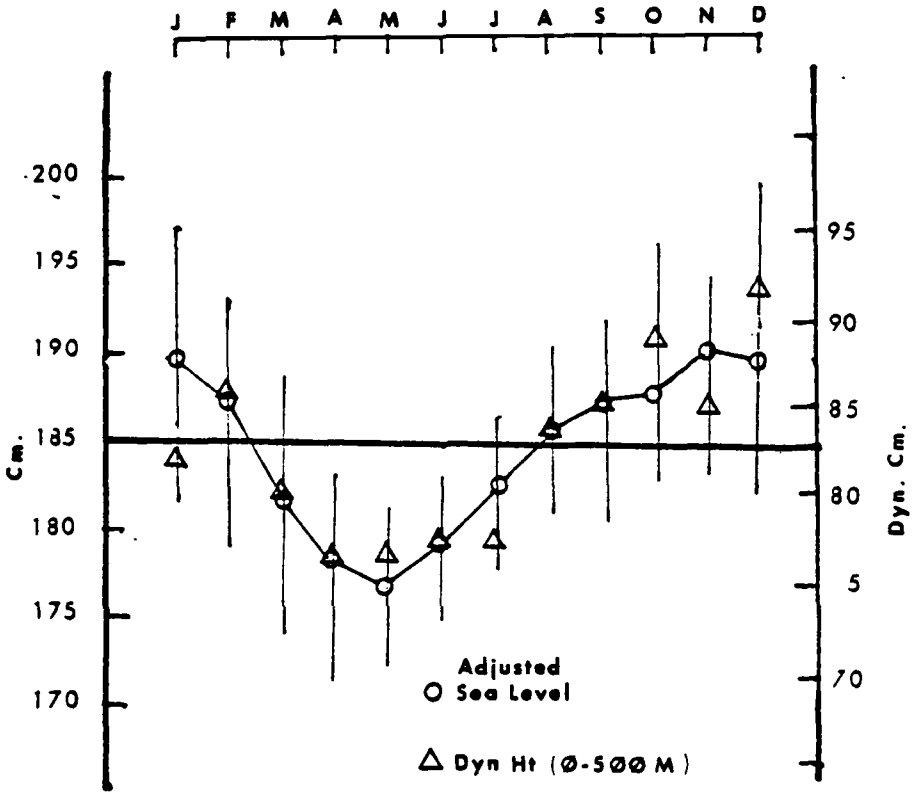


Figure 17. Seasonal Cycle of Sea Level and Dynamic Height

(Sea Level Data for Period 1963-1978 and Dynamic Height Data for Period 1968-1977. Range of Monthly Sea Levels are Vertical Bars)

winter when inshore northward flow is strongest and minimum sea levels occur during the southward flow of summer, thus relating seasonal changes in sea level to geostrophically balanced flow. Monterey lies between these two stations and has a seasonal cycle that is intermediate between these regimes.

Sea level and dynamic height are also in good agreement in a time-series sense. Figure 18 shows the Monterey time series of weekly mean sea level, calculated from the hourly data, and individual dynamic height calculations relative to 100, 300, and 500 m. The figure shows that both sea levels and dynamic heights were higher than normal during 1969-1970, 1972-1973, and 1976, which were periods of strong El Niño activity in the Eastern Tropical Pacific. Sea levels and dynamic heights were normal or near normal during non-El Niño periods. Because of the close agreement between sea level and dynamic height, and the high correlation of sea level at Monterey with that at adjacent stations, dynamic height and sea level variations both must be related to variations in the geostrophic current flow (Bretschneider and McLain, 1979).

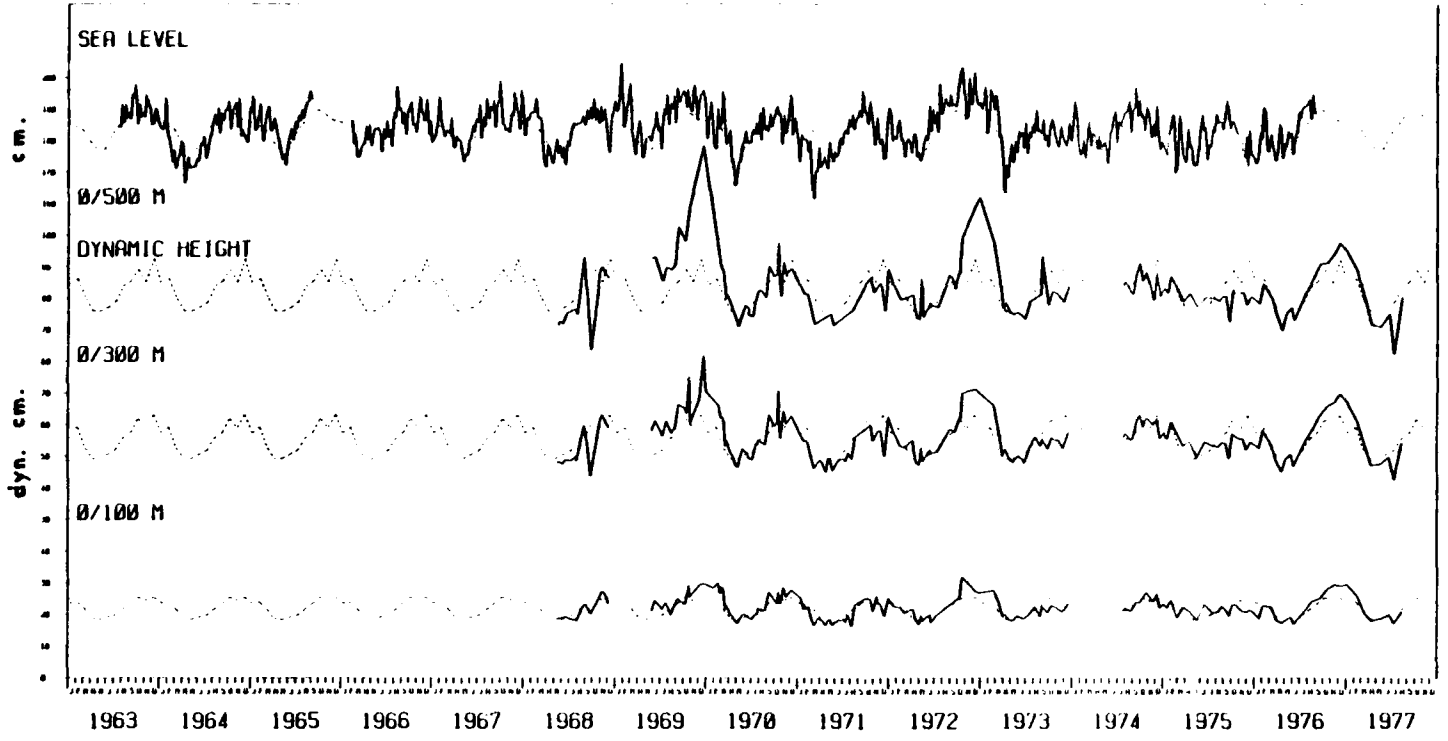


Figure 18. Time-Series of Weekly Mean Sea Level and Dynamic Height

(Mean Annual Cycles are Shown as Dotted Lines)

V. SUMMARY

Variability of sea level at Monterey, California was analyzed by various methods on a monthly, weekly, and hourly basis, and the ocean and atmospheric processes causing this variability are discussed.

Analysis of 13 years of hourly sea levels indicates that non-tidal sea level variations are small compared to the normal tide range in the area. The largest deviation of observed from predicted hourly sea levels was 39.6 cm. A seasonal change revealed by monthly frequency distributions of hourly non-tidal sea level variations was found, with observed sea levels being generally less than the predicted from March thru May and greater than the predicted from July thru January.

Monthly sea level anomalies at Monterey are correlated with anomalies recorded at tide stations from Prince Rupert, Canada to Callao, Peru but are most closely related to events affecting sea levels in the group of stations from Crescent City, California to Quepos, Costa Rica. Processes producing the El Niño phenomenon along the coast of Peru also apparently affect sea level at Monterey.

Multiple regression analysis indicates that monthly anomalies of atmospheric pressure and sea surface temperature account for most of the Monterey monthly sea level variability during both the Davidson Current and upwelling seasons. The meridional component of wind stress accounts for an additional portion of sea level variability during the upwelling season.

Analysis of six-hourly sea level and atmospheric pressure observations show that the winter spectra are more energetic than those of the upwelling season, and that most of the energy occurs in periods of 12 to 24 days. Coherence between sea level and atmospheric pressure is significant and independent of frequency. This and the constant 180° phase relationship between these six-hourly data sets

reflects the inverse response between sea level and atmospheric pressure expected from the hydrostatic relationship. The power spectra for six-hourly meridional wind stress also show a concentration of energy in low frequencies and are most energetic in winter; however, coherence between the local wind stress and sea level is generally low.

There is good agreement between the behavior of sea level and dynamic height in both a time-series and seasonal sense. The close agreement between sea level and dynamic height, and the high correlation of sea level at Monterey with that at adjacent tide stations, suggests that sea level and dynamic height both must be related to variations in the geostrophic current flow.

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APPENDIX A

MISSING HOURLY SEA LEVEL DATA

The dates and times of missing Monterey hourly sea level observations are listed below. The data series began July 21, 1963 and ended August 31, 1976.

1963

Aug 25, 12AM-Sep 04, 11 PM

Sep 28, 04AM-Oct 03, 06PM

Oct 16, 09AM-Oct 21, 11AM

1964

Mar 28, 12AM-Mar 30, 07PM

1965

Apr 01, 12AM-May 01, 09AM

Sep 01, 12AM-Dec 31, 11PM

1966

Jan 01, 12AM-Feb 03, 03PM

1969

Sep 20, 12PM-Sep 23, 03PM

1970

Oct 06, 10PM-Oct 08, 03PM

1971

Jan 20, 07PM-Jan 23, 02PM

1975

Feb 14, 01PM-Feb 18, 03PM

Oct 22, 02AM-Oct 28, 11PM

Nov 07, 01AM-Oct 19, 11PM

1976

May 25, 01AM-May 26, 11PM

APPENDIX B

MONTHLY MEAN OCEANIC AND ATMOSPHERIC OBSERVATIONS

This appendix presents graphical plots of monthly means and monthly mean anomalies of various oceanic and atmospheric observations for the period 1960 to 1978. Anomalies were calculated as the difference between a monthly mean and the long term mean (1963-1978) for the same month. Monthly means are shown as heavy lines and monthly anomalies as light lines. The data are presented in the following sequence:

1) Sea level (cm)
2) Adjusted sea level (cm)
3) Surface atmospheric pressure (mb)
4) Meridional wind stress (dynes/cm^2; positive northward)
5) Zonal wind stress (dynes/cm^2; positive eastward)
6) Offshore/Onshore Ekman transport (metric tons/sec per 100 m of coastline; positive offshore)
7) Sverdrup Transport (metric tons/ sec per km; positive northward)
8) Surface salinity (0/00)
9) Sea surface temperature (° C)

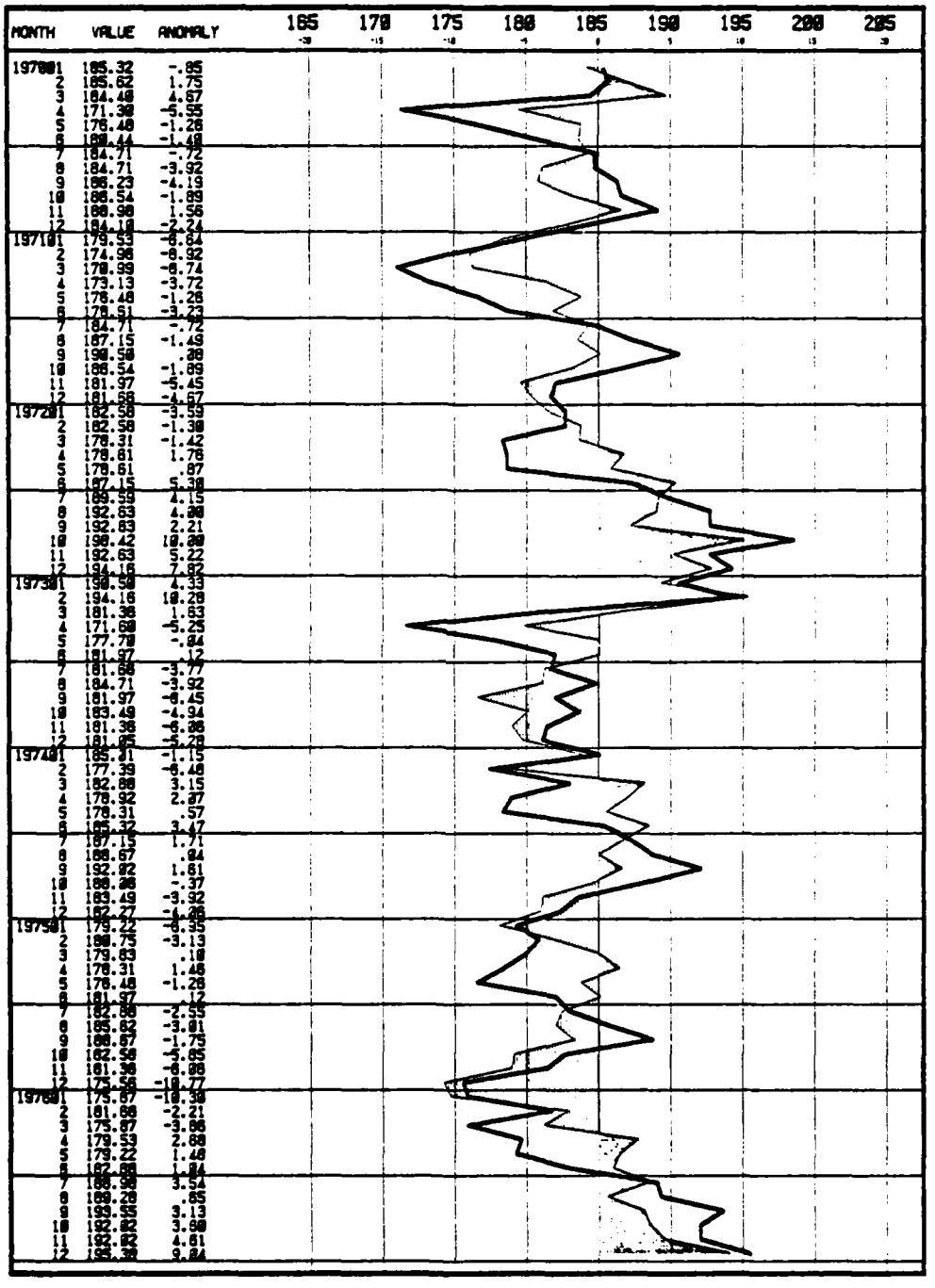
NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SEA LEVEL MONTEREY, CA BY MONTH

MONTH	VALUE	ANOMALY
196301	NO DATA	
2	NO DATA	
3	NO DATA	
4	NO DATA	
5	NO DATA	
6	NO DATA	
7	187.76	2.32
8	180.37	-.27
9	194.18	3.74
10	189.59	1.16
11	190.20	2.78
12	187.15	.81
196401	185.62	-.54
2	177.09	-6.79
3	175.87	-3.86
4	171.91	-4.94
5	172.21	-5.53
6	178.00	-3.84
7	180.75	-4.69
8	187.15	-1.49
9	189.28	-1.14
10	180.37	-.08
11	184.71	-2.70
12	185.01	-1.32
196501	187.76	1.59
2	184.71	.83
3	186.84	7.11
4	NO DATA	
5	178.17	-1.58
6	183.49	1.85
7	187.45	2.02
8	193.24	4.61
9	NO DATA	
10	NO DATA	
11	NO DATA	
12	NO DATA	
196601	NO DATA	
2	181.97	-1.91
3	177.09	-2.64
4	182.27	5.42
5	184.10	6.36
6	181.66	-.18
7	183.49	-1.94
8	190.58	1.87
9	187.76	-2.66
10	185.93	-2.50
11	189.89	2.48
12	185.62	-.71
196701	186.54	.37
2	182.58	-1.30
3	181.97	2.24
4	179.22	2.37
5	177.09	-.85
6	185.21	3.17
7	186.54	1.10
8	191.11	2.48
9	192.22	1.61
10	183.49	-4.94
11	190.58	3.09
12	188.26	1.73
196801	187.45	1.28
2	188.67	4.00
3	178.61	-1.12
4	175.87	-.98
5	177.39	-.35
6	177.39	-4.45
7	185.01	-.42
8	186.54	-2.10
9	189.28	-1.14
10	188.67	.24
11	185.62	-1.79
12	186.84	.51
196901	194.18	7.39
2	192.83	6.76
3	180.44	.71
4	179.83	2.98
5	181.97	4.23
6	184.40	2.56
7	188.37	2.33
8	190.58	1.87
9	194.77	4.35
10	192.22	3.60
11	192.94	5.53
12	191.72	5.38

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP, MONTEREY, CALIFORNIA

SEA LEVEL MONTEREY, CA BY MONTH

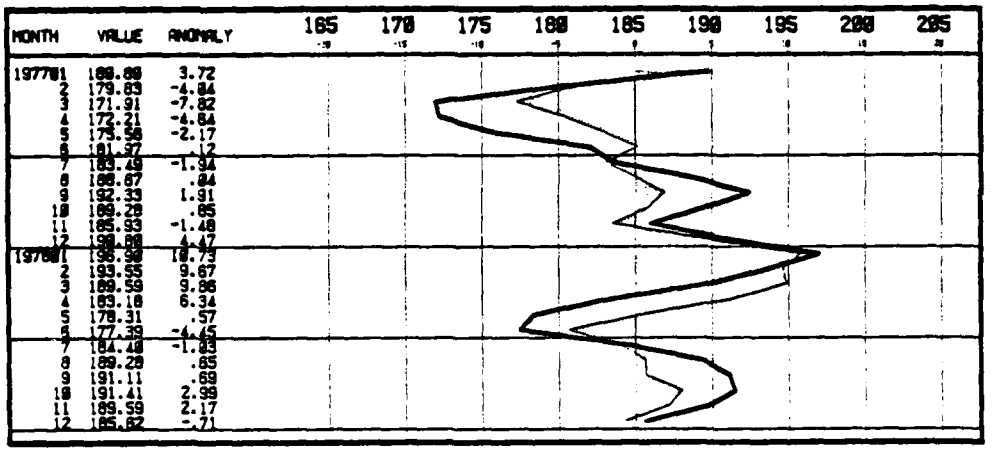


MONTH	VALUE	ANOMALY
197801	185.32	-.85
2	185.62	1.75
3	184.48	4.67
4	171.30	-5.55
5	178.48	-1.28
6	180.44	-1.48
7	184.71	-.72
8	184.71	-3.92
9	186.23	-4.19
10	186.54	-1.89
11	180.90	1.56
12	184.18	-2.24
197901	179.53	-6.84
2	174.98	-8.92
3	178.99	-6.74
4	173.13	-3.72
5	176.48	-1.28
6	178.61	-3.23
7	184.71	-.72
8	187.15	-1.49
9	190.58	.20
10	186.54	-1.89
11	181.97	-5.45
12	181.68	-4.67
198001	182.58	-3.59
2	182.58	-1.38
3	178.31	-1.42
4	178.61	1.76
5	178.61	.87
6	187.15	5.38
7	189.59	4.15
8	192.63	4.80
9	192.83	2.21
10	196.42	10.20
11	192.63	5.22
12	194.16	7.82
198101	190.58	4.33
2	194.16	10.20
3	181.38	1.83
4	171.60	-5.25
5	177.70	-.94
6	181.97	.12
7	181.68	-3.77
8	184.71	-3.92
9	181.97	-6.45
10	183.49	-4.94
11	181.38	-6.36
12	181.05	-5.28
198201	185.81	-1.15
2	177.39	-8.48
3	182.88	3.15
4	178.92	2.97
5	178.31	.57
6	185.32	3.47
7	187.15	1.71
8	188.67	.84
9	192.02	1.61
10	188.28	-.37
11	183.49	-3.92
12	182.27	-4.26
198301	179.22	-8.55
2	190.75	-3.13
3	179.83	.10
4	178.31	1.48
5	178.48	-1.28
6	181.97	-.12
7	182.88	-2.55
8	185.82	-3.81
9	188.67	-1.75
10	182.58	-5.85
11	181.38	-6.88
12	175.56	-10.77
198401	175.87	-10.38
2	181.68	-2.21
3	175.87	-3.96
4	179.53	2.68
5	179.22	1.48
6	182.88	1.84
7	188.98	3.54
8	189.28	.65
9	193.55	3.13
10	192.02	3.80
11	192.02	4.61
12	193.39	9.84

NOAA-NMFS, PACIFIC ENVIRONMENTAL GROUP, MONTEREY, CALIFORNIA

SEA LEVEL — MONTEREY, CA — BY MONTH

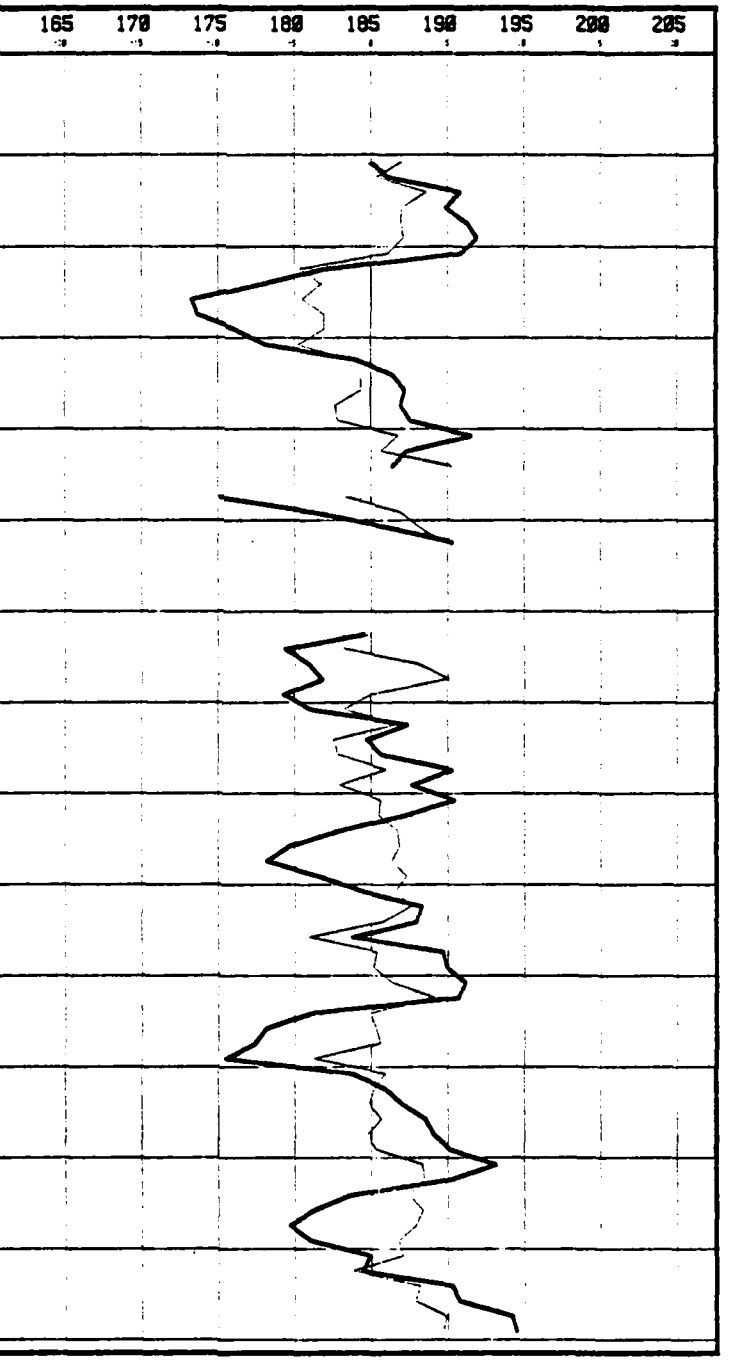
MONTH	VALUE	ANOMALY
1977 1	188.68	3.72
2	179.83	-4.84
3	171.91	-7.82
4	172.21	-4.84
5	175.58	-2.17
6	181.57	.12
7	183.48	-1.94
8	188.67	.84
9	192.33	1.91
10	189.28	.85
11	185.93	-1.48
12	190.88	4.47
1978 1	196.98	10.79
2	193.55	9.67
3	189.59	9.86
4	183.18	6.34
5	178.31	.57
6	177.39	-4.45
7	184.48	-1.83
8	189.28	.85
9	191.11	.69
10	191.41	2.99
11	189.59	2.17
12	185.82	-.71



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

ADJ. SEA LEVEL MONTEREY, CA BY MONTH

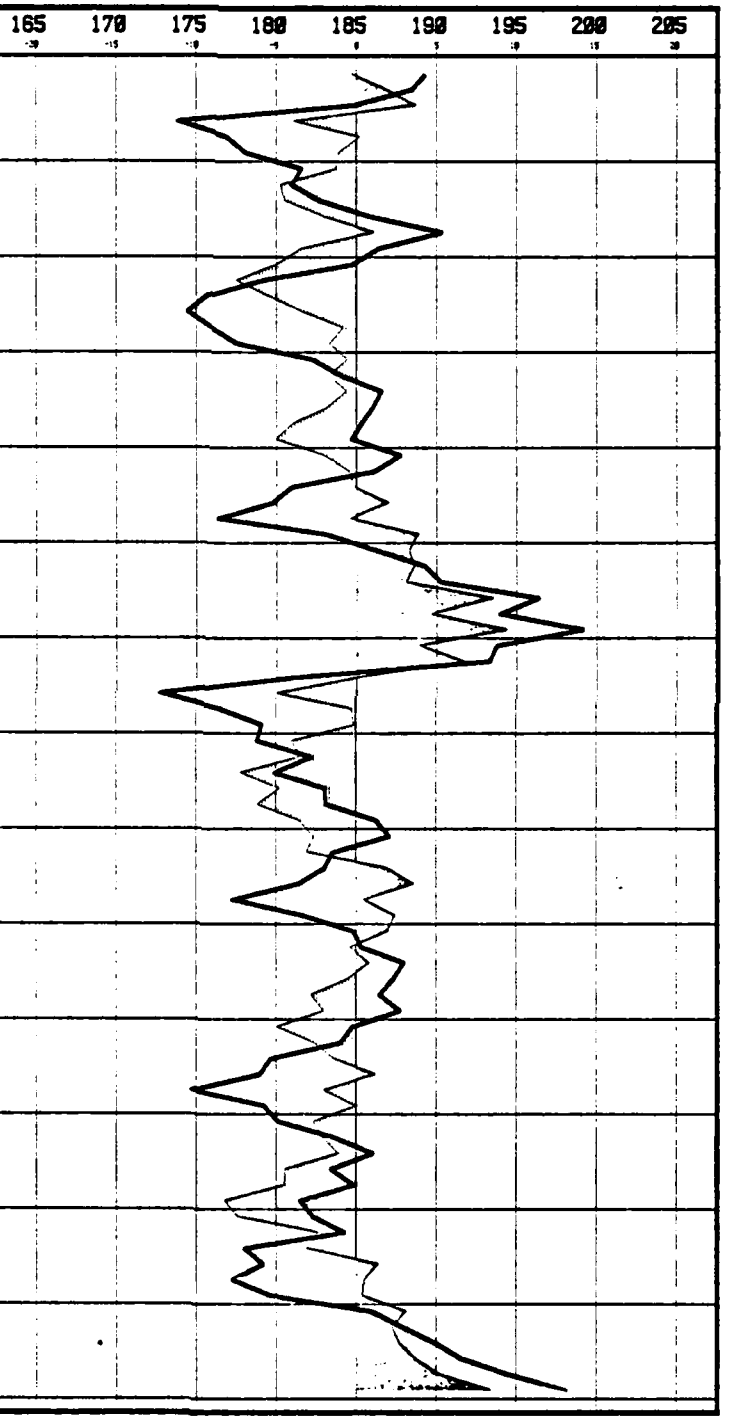
MONTH	VALUE	ANOMALY
196301	NO DATA	
2	NO DATA	
3	NO DATA	
4	NO DATA	
5	NO DATA	
6	NO DATA	
7	184.85	2.88
8	180.38	.42
9	190.75	3.62
10	189.78	1.98
11	191.19	1.95
12	191.84	2.12
196401	190.81	1.09
2	181.80	-4.69
3	177.76	-3.30
4	173.20	-4.56
5	173.60	-3.11
6	176.29	-3.10
7	178.04	-4.75
8	183.94	-1.70
9	186.37	-.76
10	187.16	-.64
11	186.90	-2.34
12	187.58	-2.22
196501	191.45	1.73
2	187.20	.63
3	188.33	5.27
4	NO DATA	
5	174.97	-1.74
6	181.28	1.89
7	185.94	3.15
8	190.23	4.59
9	NO DATA	
10	NO DATA	
11	NO DATA	
12	NO DATA	
196601	NO DATA	
2	184.66	-1.91
3	179.28	-1.78
4	180.86	3.10
5	181.69	4.98
6	179.25	.06
7	180.98	-1.81
8	187.29	1.65
9	184.65	-2.48
10	185.62	-2.18
11	190.18	.94
12	187.61	-2.11
196701	190.33	.61
2	187.07	.50
3	182.76	1.70
4	179.61	1.85
5	178.88	1.37
6	181.58	2.31
7	184.33	1.54
8	188.20	2.56
9	187.92	.79
10	183.58	-4.12
11	189.59	.35
12	189.85	.13
196801	191.24	1.32
2	190.66	4.09
3	181.00	-.26
4	178.86	.38
5	177.28	.57
6	175.30	-3.81
7	183.78	.91
8	185.83	.19
9	186.97	-.16
10	188.46	.66
11	189.01	-.23
12	190.03	.31
196901	193.05	3.33
2	190.82	3.45
3	183.53	2.47
4	181.12	3.38
5	179.36	2.95
6	181.20	1.81
7	184.88	2.87
8	184.39	-1.25
9	190.28	3.13
10	190.72	2.92
11	194.13	4.89
12	194.41	4.69



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP, MONTEREY, CALIFORNIA

ADJ SEA LEVEL MONTEREY, CA BY MONTH

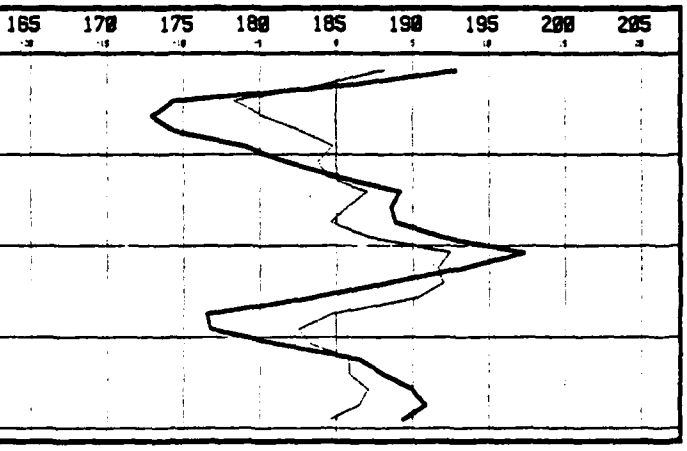
MONTH	VALUE	ANOMALY
197001	189.31	-.41
2	188.41	1.84
3	184.70	3.64
4	173.79	-3.97
5	176.87	.16
6	178.03	-1.16
7	181.50	-1.29
8	180.90	-4.74
9	182.82	-4.51
10	185.73	-2.07
11	190.27	1.03
12	186.29	-3.43
197101	184.72	-5.00
2	179.05	-7.52
3	175.58	-5.48
4	174.42	-3.34
5	175.87	-.84
6	177.50	-1.69
7	182.20	-.59
8	183.94	-1.70
9	186.49	-.64
10	185.93	-1.87
11	185.28	-3.98
12	184.65	-5.27
197201	187.67	-2.05
2	186.27	-.50
3	188.90	-.16
4	179.70	1.94
5	176.30	-.41
6	183.04	3.85
7	186.08	3.29
8	189.22	3.58
9	190.22	3.09
10	196.32	8.52
11	193.92	4.68
12	188.05	3.33
197301	193.69	3.97
2	193.25	6.68
3	181.15	.09
4	172.69	-5.27
5	176.39	-.32
6	179.26	-.13
7	178.75	-4.24
8	182.10	-3.54
9	179.86	-7.27
10	182.98	-4.82
11	183.85	-6.19
12	186.14	-3.58
197401	187.20	-2.72
2	183.48	-3.09
3	182.97	1.91
4	181.31	3.55
5	177.20	.49
6	181.61	2.42
7	184.74	1.95
8	185.26	-.38
9	187.92	.79
10	187.25	-.55
11	186.30	-2.86
12	187.56	-2.06
197501	184.71	-5.01
2	183.94	-2.63
3	179.62	-1.44
4	178.90	1.14
5	174.67	-2.84
6	179.16	-.83
7	180.87	-2.72
8	183.51	-2.13
9	185.96	-1.17
10	183.37	-4.43
11	184.74	-4.58
12	181.46	-8.28
197601	182.28	-7.46
2	184.15	-2.42
3	177.96	-3.10
4	179.12	1.36
5	177.21	.50
6	179.57	.36
7	185.87	3.08
8	187.87	2.23
9	189.84	2.71
10	191.52	3.72
11	194.42	5.18
12	190.87	8.35



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

ADJ. SEA LEVEL MONTEREY, CA BY MONTH

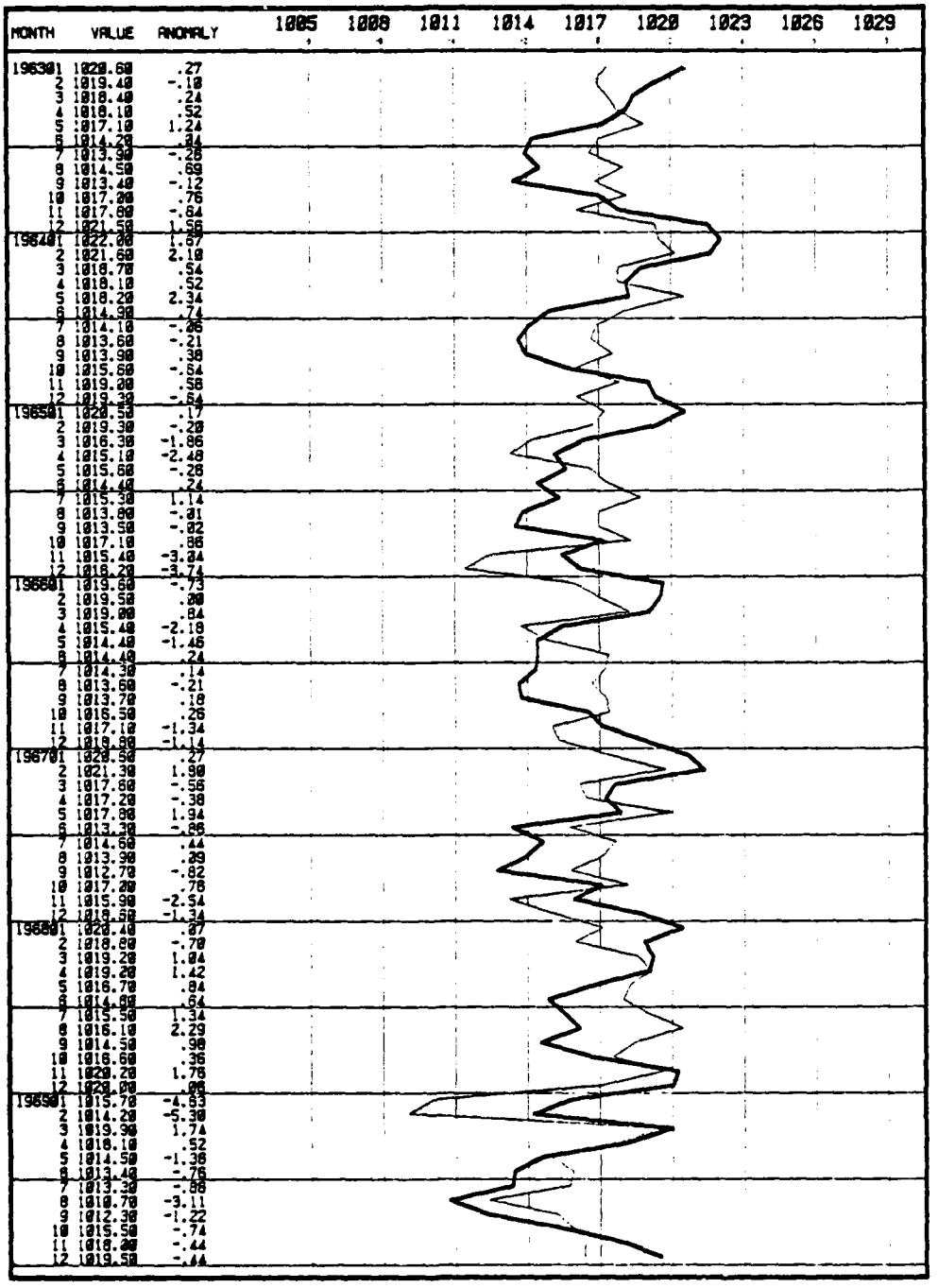
MONTH	VALUE	ANOMALY
197701	192.80	3.16
2	185.52	-1.05
3	174.30	-6.76
4	172.90	-4.86
5	174.36	-2.35
6	178.96	-.23
7	181.58	-1.21
8	184.96	-.58
9	189.12	1.99
10	188.57	.77
11	188.82	-.42
12	191.90	2.18
197801	197.19	7.47
2	193.24	6.67
3	188.00	7.02
4	182.98	5.22
5	176.50	-.21
6	176.68	-2.51
7	181.10	-1.69
8	186.47	.83
9	188.00	.87
10	189.91	2.11
11	190.78	1.54
12	189.31	-.41



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

PRESSURE

BY MONTH

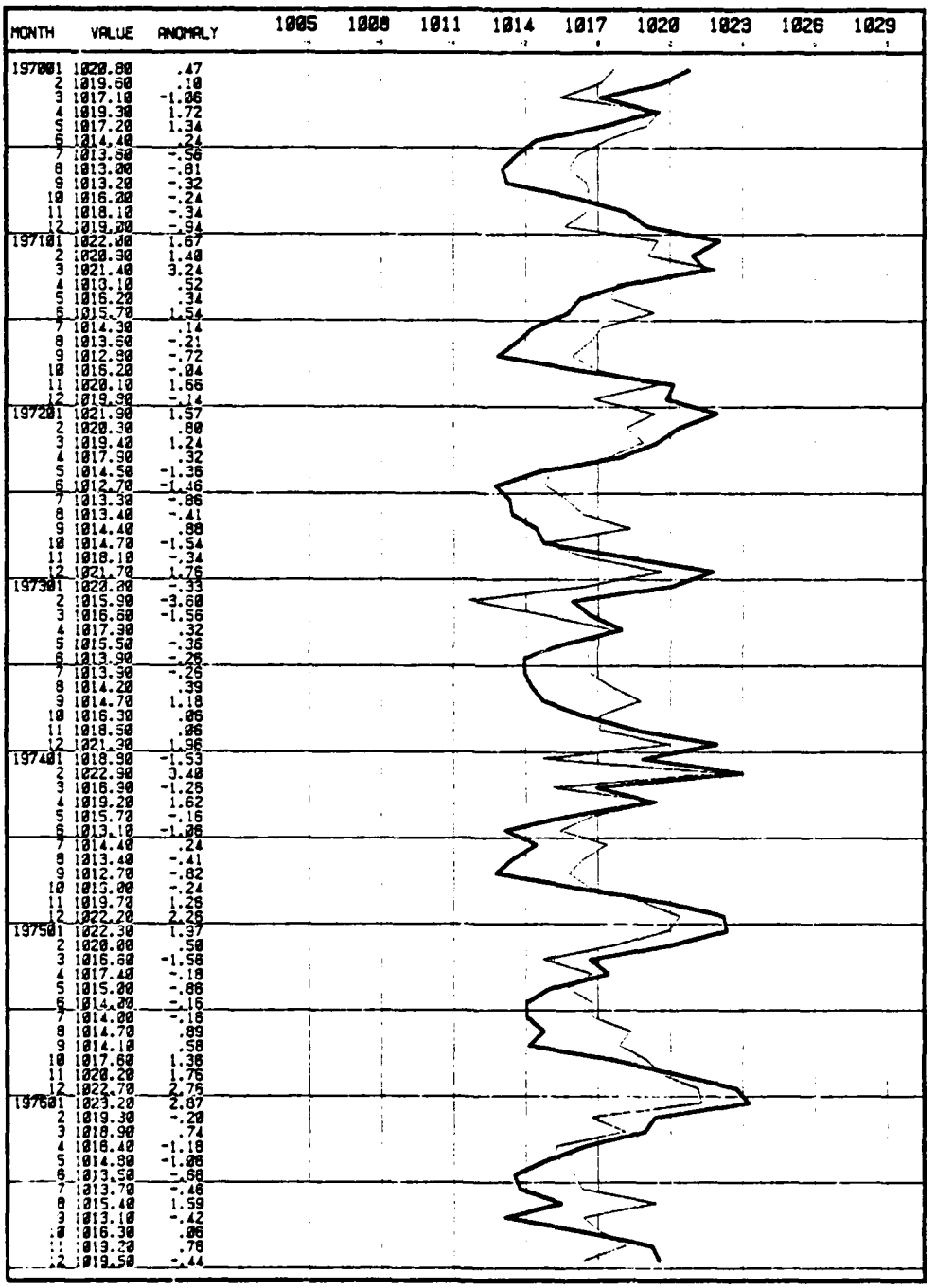


MONTH	VALUE	ANOMALY
196301	1020.60	.27
2	1019.40	-.10
3	1018.40	.24
4	1018.10	.52
5	1017.10	1.24
6	1014.20	.04
7	1013.90	-.26
8	1014.50	.69
9	1013.40	-.12
10	1017.20	.76
11	1017.80	-.84
12	1021.50	1.56
196401	1022.00	1.67
2	1021.60	2.10
3	1018.70	.54
4	1018.10	.52
5	1018.20	2.34
6	1014.90	.74
7	1014.10	-.26
8	1013.60	-.21
9	1013.90	.38
10	1015.60	-.64
11	1019.20	.56
12	1019.30	-.64
196501	1020.50	.17
2	1019.30	-.20
3	1016.30	-1.86
4	1015.10	-2.48
5	1015.60	-.28
6	1014.40	.24
7	1015.30	1.14
8	1013.80	-.01
9	1013.50	-.02
10	1017.10	.86
11	1015.40	-3.04
12	1016.20	-3.74
196601	1019.60	-.73
2	1019.50	.20
3	1019.00	.84
4	1015.40	-2.18
5	1014.40	-1.46
6	1014.40	.24
7	1014.30	-.14
8	1013.60	-.21
9	1013.70	.18
10	1016.50	.26
11	1017.10	-1.34
12	1018.00	-1.14
196701	1020.50	.27
2	1021.30	1.90
3	1017.60	-.56
4	1017.20	-.38
5	1017.80	1.94
6	1013.30	-.86
7	1014.60	.44
8	1013.90	.29
9	1012.70	-.82
10	1017.20	.76
11	1015.90	-2.54
12	1018.50	-1.34
196801	1020.40	.07
2	1018.80	-.70
3	1019.20	1.04
4	1019.20	1.42
5	1016.70	.84
6	1014.00	.64
7	1015.50	1.34
8	1016.10	2.29
9	1014.50	.90
10	1016.60	.36
11	1020.20	1.76
12	1020.00	.06
196901	1015.70	-4.53
2	1014.20	-5.30
3	1019.90	1.74
4	1018.10	.52
5	1014.50	-1.36
6	1013.40	-.76
7	1013.30	-.86
8	1010.70	-3.11
9	1012.30	-1.22
10	1015.50	-.74
11	1018.00	-.44
12	1019.50	-.44

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

PRESSURE BY MONTH

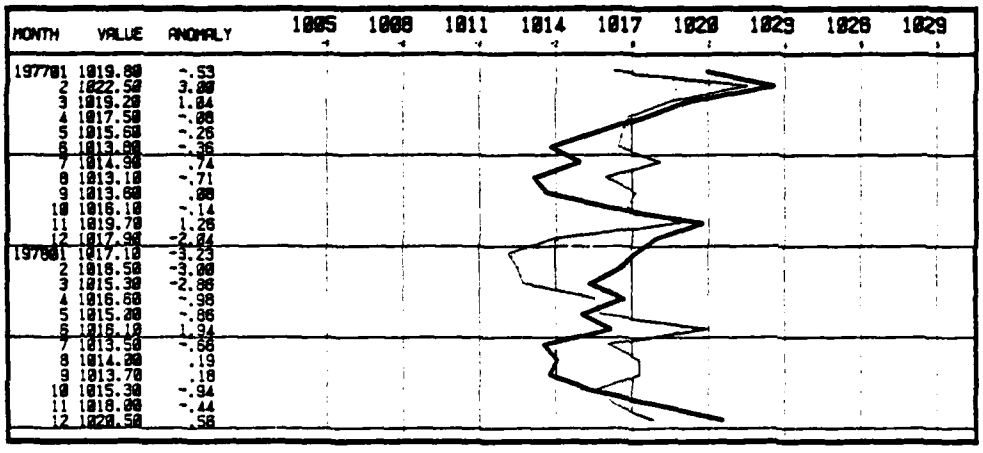
MONTH	VALUE	ANOMALY
197001	1020.80	.47
2	1019.60	.10
3	1017.10	-1.06
4	1019.30	1.72
5	1017.20	1.34
6	1014.40	.24
7	1013.60	-.56
8	1013.20	-.81
9	1013.20	-.32
10	1016.20	-.24
11	1018.10	-.34
12	1019.20	-.94
197101	1022.40	1.67
2	1020.30	1.40
3	1021.40	3.24
4	1013.10	.52
5	1016.20	.34
6	1015.70	1.54
7	1014.30	.14
8	1013.60	-.21
9	1012.90	-.72
10	1016.20	-.04
11	1020.10	1.66
12	1019.90	-.14
197201	1021.90	1.57
2	1020.30	.80
3	1019.40	1.24
4	1017.90	.32
5	1014.50	-1.36
6	1012.70	-1.46
7	1013.30	-.86
8	1013.40	-.41
9	1014.40	.88
10	1014.70	-1.54
11	1018.10	-.34
12	1021.70	1.76
197301	1020.30	-.33
2	1015.90	-3.60
3	1016.60	-1.56
4	1017.30	.32
5	1015.50	-.36
6	1013.90	-.26
7	1013.30	-.26
8	1014.20	.39
9	1014.70	1.18
10	1016.30	.06
11	1018.50	.06
12	1021.30	1.96
197401	1018.90	-1.53
2	1022.90	3.40
3	1016.90	-1.26
4	1019.20	1.62
5	1015.70	-.16
6	1013.10	-1.06
7	1014.40	.24
8	1013.40	-.41
9	1012.70	-.82
10	1015.00	-.24
11	1019.70	1.28
12	1022.20	2.26
197501	1022.30	1.97
2	1020.00	.50
3	1016.60	-1.56
4	1017.40	-.18
5	1015.00	-.86
6	1014.00	-.16
7	1014.00	-.16
8	1014.70	.89
9	1014.10	.58
10	1017.60	1.36
11	1020.20	1.76
12	1022.70	2.76
197601	1023.20	2.87
2	1019.30	-.20
3	1018.90	.74
4	1016.40	-1.18
5	1014.80	-1.06
6	1013.50	-.66
7	1013.70	-.46
8	1015.40	1.59
9	1013.10	-.42
10	1016.30	.06
11	1019.20	.76
12	1019.50	.44



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP, MONTEREY, CALIFORNIA

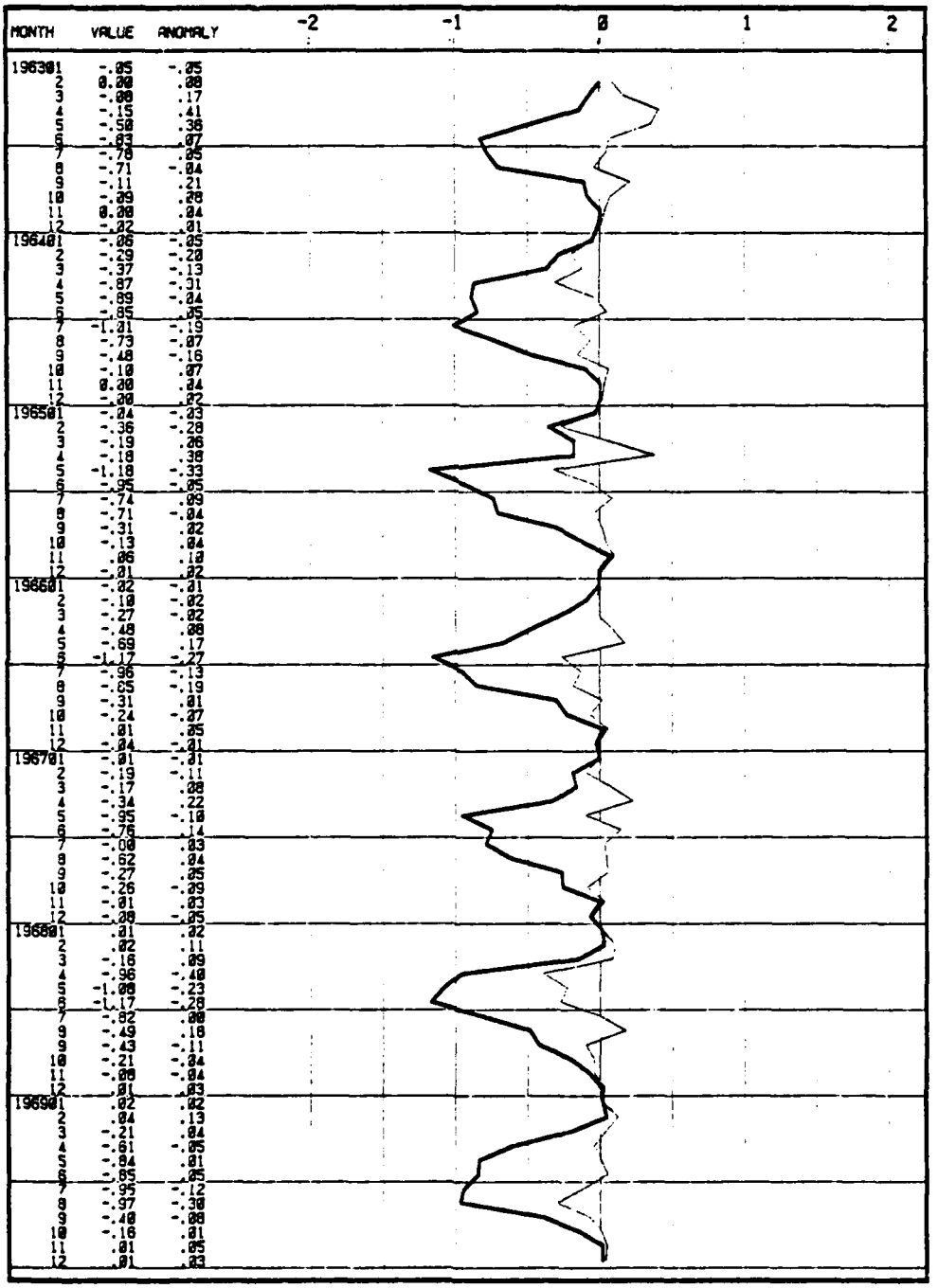
PRESSURE BY MONTH

MONTH	VALUE	ANOMALY
197701	1019.80	-.53
2	1022.50	3.00
3	1019.20	1.04
4	1017.50	-.00
5	1015.60	-.26
6	1013.80	-.36
7	1014.30	.74
8	1013.10	-.71
9	1013.60	.00
10	1016.10	-.14
11	1019.70	1.26
12	1017.90	-2.04
197801	1017.10	-3.23
2	1018.50	-3.00
3	1015.30	-2.80
4	1016.60	-.98
5	1015.20	-.86
6	1016.10	1.94
7	1013.50	-.66
8	1014.20	.19
9	1013.70	.10
10	1015.30	-.94
11	1018.00	-.44
12	1020.50	.56



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

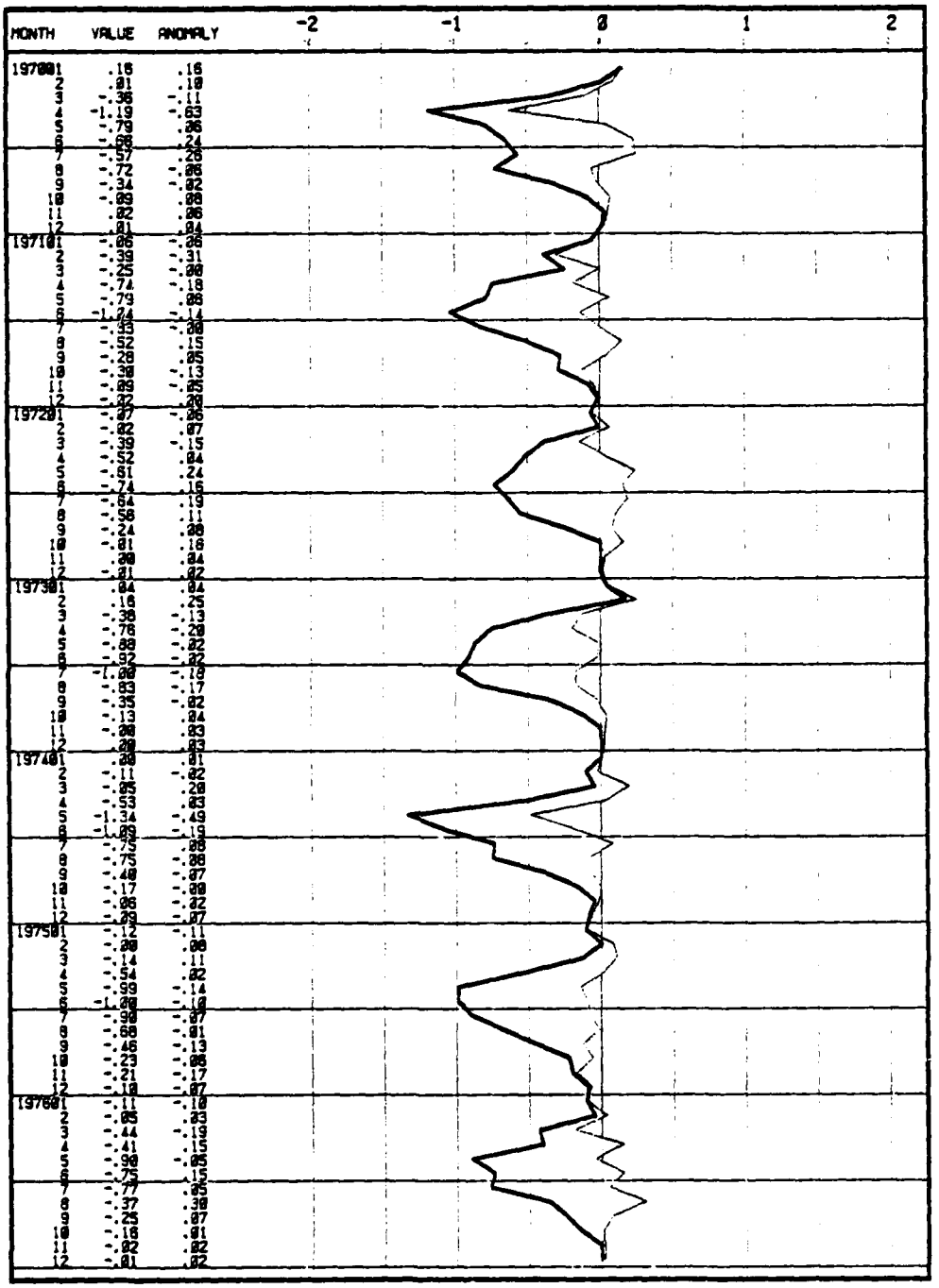
N. COMP. WIND STRESS BY MONTH



MONTH	VALUE	ANOMALY
196301	-.05	-.05
2	0.00	.00
3	-.00	.17
4	-.15	.41
5	-.50	.36
6	-.83	.07
7	-.78	.05
8	-.71	-.04
9	-.11	.21
10	-.09	.28
11	0.00	.04
12	-.02	.01
196401	-.06	-.05
2	-.29	-.20
3	-.37	-.13
4	-.87	-.31
5	-.89	-.04
6	-.85	.05
7	-1.01	-.19
8	-.73	-.07
9	-.48	-.16
10	-.10	.07
11	0.00	.04
12	-.00	.02
196501	-.04	-.03
2	-.36	-.28
3	-.19	.06
4	-.18	.38
5	-1.18	-.33
6	-.95	-.05
7	-.74	.09
8	-.71	-.04
9	-.31	.02
10	-.13	.04
11	.06	.10
12	-.01	.02
196601	-.02	-.01
2	-.10	-.02
3	-.27	-.02
4	-.48	.08
5	-.69	.17
6	-1.17	-.27
7	-.96	-.13
8	-.85	-.19
9	-.31	.01
10	-.24	-.27
11	.01	.05
12	-.04	-.01
196701	-.01	-.01
2	-.19	-.11
3	-.17	.08
4	-.34	.22
5	-.95	-.10
6	-.76	.14
7	-.00	.83
8	-.62	.04
9	-.27	.05
10	-.26	-.09
11	-.01	.03
12	-.08	-.05
196801	.01	.02
2	.02	.11
3	-.16	.09
4	-.96	-.48
5	-1.00	-.23
6	-1.17	-.28
7	-.82	.00
8	-.49	.16
9	-.43	-.11
10	-.21	-.04
11	-.00	-.04
12	.01	.03
196901	.02	.02
2	.04	.13
3	-.21	.04
4	-.61	-.05
5	-.84	.01
6	-.85	.05
7	-.95	-.12
8	-.97	-.30
9	-.40	-.08
10	-.16	.01
11	.01	.05
12	.01	.03

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

N. COMP. WIND STRESS BY MONTH

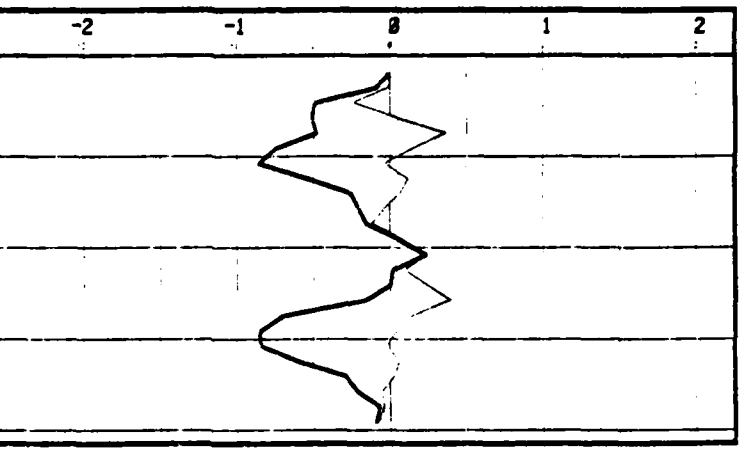


MONTH	VALUE	ANOMALY
197801	.16	.16
2	.01	.10
3	-.36	-.11
4	-1.19	-.63
5	-.79	.06
6	-.08	.24
7	-.57	.26
8	-.72	-.06
9	-.34	-.02
10	-.09	.00
11	.02	.06
12	.01	.04
197101	-.06	-.06
2	-.39	-.31
3	-.25	-.00
4	-.74	-.18
5	-.79	.00
6	-1.24	-.14
7	-.93	-.00
8	-.52	.15
9	-.28	.05
10	-.30	-.13
11	-.09	-.05
12	-.02	.00
197201	-.07	-.06
2	-.02	.07
3	-.39	-.15
4	-.52	.04
5	-.81	.24
6	-.74	.16
7	-.64	.19
8	-.58	.11
9	-.24	.00
10	-.01	.16
11	.00	.04
12	-.01	.02
197301	.04	.04
2	.16	.25
3	-.38	-.13
4	-.78	-.20
5	-.88	-.02
6	-.92	-.02
7	-1.00	-.10
8	-.83	-.17
9	-.35	-.02
10	-.13	.04
11	-.00	.03
12	.00	.03
197401	.00	.01
2	-.11	-.02
3	-.05	.20
4	-.53	.03
5	-1.34	-.49
6	-1.09	-.19
7	-.75	.08
8	-.75	-.08
9	-.40	-.07
10	-.17	-.00
11	-.06	-.02
12	-.09	-.07
197501	-.12	-.11
2	-.00	.08
3	-.14	.11
4	-.54	.02
5	-.99	-.14
6	-1.00	-.10
7	-.90	-.07
8	-.68	-.01
9	-.46	-.13
10	-.23	-.06
11	-.21	-.17
12	-.10	-.07
197601	-.11	-.10
2	-.05	.03
3	-.44	-.19
4	-.41	.15
5	-.90	-.05
6	-.75	.15
7	-.77	.05
8	-.37	.30
9	-.25	.07
10	-.16	.01
11	-.02	.02
12	-.01	.02

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

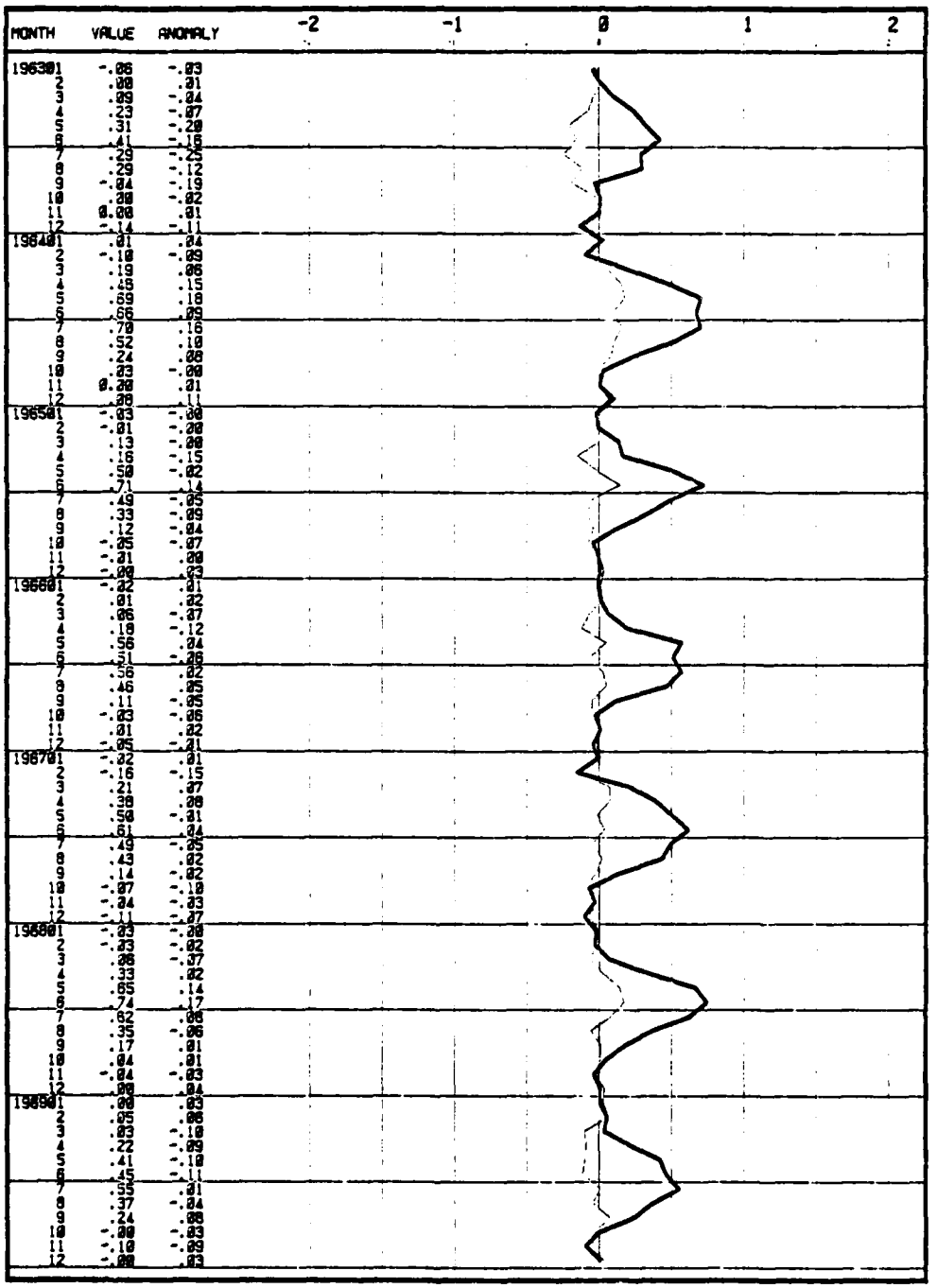
N. COMP. WIND STRESS BY MONTH

MONTH	VALUE	ANOMALY
197701	-.01	.00
2	-.10	-.01
3	-.49	-.25
4	-.52	.05
5	-.49	.36
6	-.78	.14
7	-.86	-.03
8	-.55	.12
9	-.28	.08
10	-.21	-.04
11	-.16	-.12
12	.05	.07
197801	.22	.23
2	.01	.09
3	-.01	.24
4	-.17	.39
5	-.70	.15
6	-.85	.24
7	-.85	-.02
8	-.61	.06
9	-.30	.03
10	-.22	-.25
11	-.38	-.24
12	-.10	-.38



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

EAST COMP. WIND STRESS BY MONTH



MONTH	VALUE	ANOMALY
196301	-.08	-.03
2	.00	.01
3	.09	-.04
4	.23	-.07
5	.31	-.20
6	.41	-.16
7	.29	-.25
8	.29	-.12
9	-.04	-.19
10	.00	-.02
11	0.00	.01
12	-.14	-.11
196401	.01	.04
2	-.10	-.09
3	.19	.06
4	.45	.15
5	.69	.18
6	.66	.09
7	.70	.16
8	.52	.10
9	.24	.06
10	.03	-.00
11	0.20	.01
12	.00	.11
196501	-.03	-.00
2	-.01	-.00
3	.13	-.00
4	.16	-.15
5	.50	-.02
6	.71	.14
7	.49	-.05
8	.33	-.09
9	.12	-.04
10	-.05	-.07
11	-.01	.00
12	-.00	.03
196601	-.22	.01
2	.01	.02
3	.06	-.07
4	.18	-.12
5	.56	.04
6	.51	-.06
7	.56	.02
8	.46	.05
9	.11	-.05
10	-.03	-.06
11	.01	.02
12	-.05	-.01
196701	-.22	.01
2	-.16	-.15
3	.21	.07
4	.30	.00
5	.50	-.01
6	.61	.04
7	.49	-.05
8	.43	.02
9	.14	-.02
10	-.07	-.10
11	-.04	-.03
12	-.11	-.07
196801	-.03	-.00
2	-.03	-.02
3	.06	-.07
4	.33	.02
5	.65	.14
6	.74	.17
7	.62	.08
8	.35	-.06
9	.17	.01
10	.04	.01
11	-.04	-.03
12	.00	.04
196901	.00	.03
2	.05	.06
3	.03	-.10
4	.22	-.09
5	.41	-.10
6	.45	-.11
7	.55	.01
8	.37	-.04
9	.24	.00
10	-.00	-.03
11	-.10	-.09
12	-.00	.03

NOAA-NMFS. PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

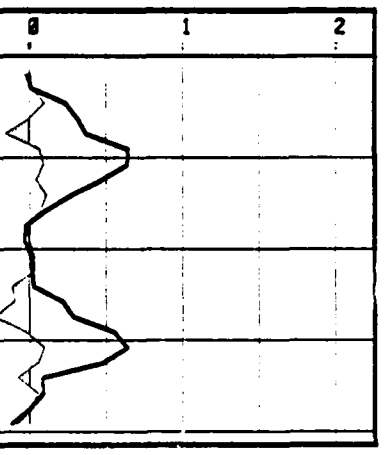
EAST COMP. WIND STRESS BY MONTH

MONTH	VALUE	ANOMALY
197001	.03	.00
2	-.03	-.02
3	.00	-.05
4	.49	.18
5	.41	-.11
6	.36	-.20
7	.32	-.22
8	.40	-.02
9	.09	-.07
10	.04	.01
11	.01	.01
12	-.01	.05
197101	-.04	-.02
2	.01	.02
3	.00	-.05
4	.36	.06
5	.45	-.07
6	.57	.00
7	.43	-.11
8	.24	-.17
9	.05	-.11
10	0.00	-.03
11	-.01	.00
12	.01	.04
197201	-.10	-.07
2	-.01	.00
3	.09	-.05
4	.27	-.04
5	.43	-.08
6	.56	-.01
7	.47	-.06
8	.41	-.00
9	.17	.01
10	.00	-.02
11	-.00	.01
12	-.01	.02
197301	.01	.04
2	-.01	-.00
3	.32	.19
4	.36	.05
5	.33	-.11
6	.56	-.01
7	.58	.15
8	.60	.19
9	.21	.05
10	.04	.02
11	.13	.13
12	.00	.03
197401	-.00	.02
2	.01	.02
3	.15	.02
4	.20	-.03
5	.09	.37
6	.04	.07
7	.52	-.02
8	.54	.12
9	.25	.09
10	.10	.07
11	-.01	.00
12	-.00	-.03
197501	-.05	-.02
2	.00	.07
3	.20	.06
4	.43	.12
5	.59	.07
6	.75	.19
7	.69	.15
8	.47	.06
9	.20	.12
10	.11	.08
11	-.00	.00
12	-.03	-.02
197601	-.10	-.08
2	.03	.04
3	.17	.04
4	.26	-.05
5	.59	.07
6	.37	-.19
7	.56	-.02
8	.27	-.15
9	.19	.03
10	.04	.01
11	-.04	-.03
12	-.00	-.02

NOAA-NMFS. PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

EAST COMP. WIND STRESS BY MONTH

MONTH	VALUE	ANOMALY
197701	-.02	.00
2	.00	.01
3	.25	.10
4	.31	.00
5	.36	-.15
6	.84	.27
7	.53	.09
8	.46	.05
9	.27	.11
10	.10	.07
11	-.03	-.02
12	-.03	.00
197801	.00	.03
2	.02	.03
3	.02	-.11
4	.21	-.10
5	.28	-.24
6	.55	-.02
7	.53	.09
8	.47	.06
9	.00	-.00
10	.00	.06
11	0.00	.01
12	-.12	-.00

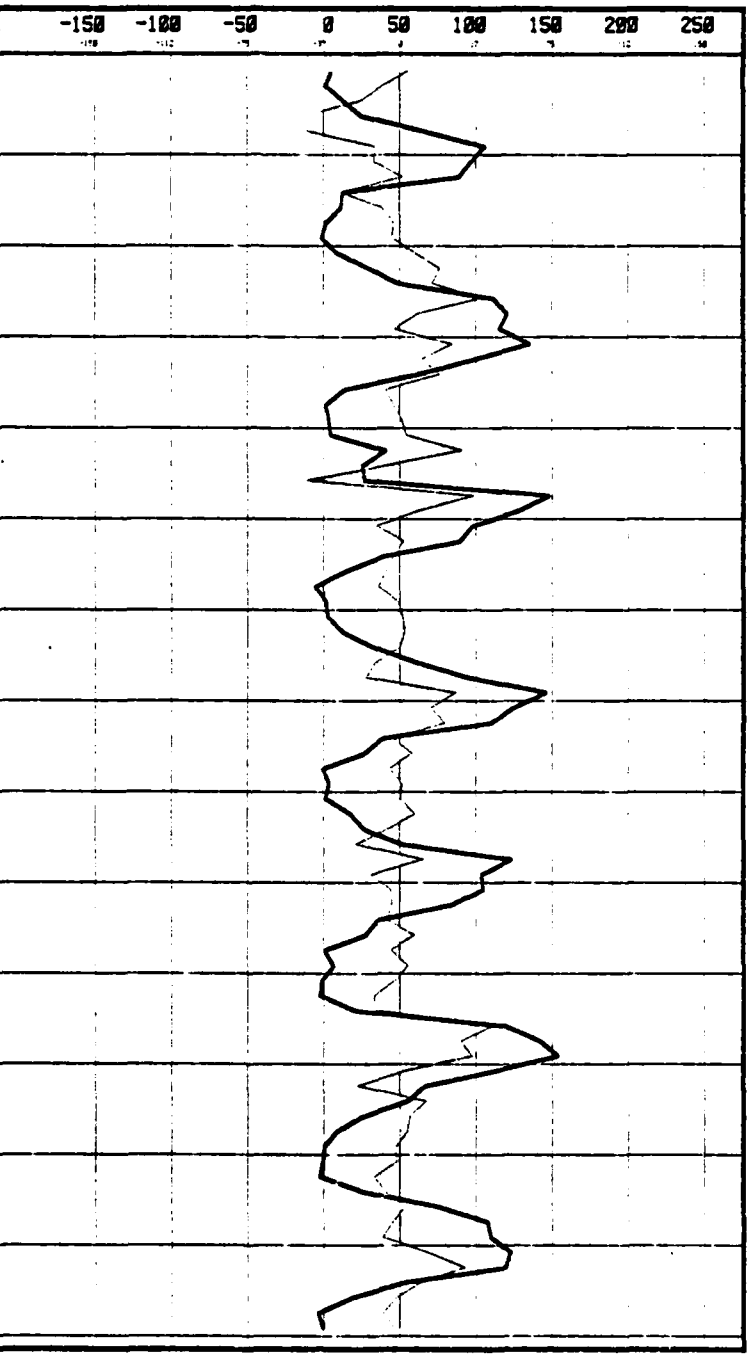


NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

EKMAN TSPT

BY MONTH

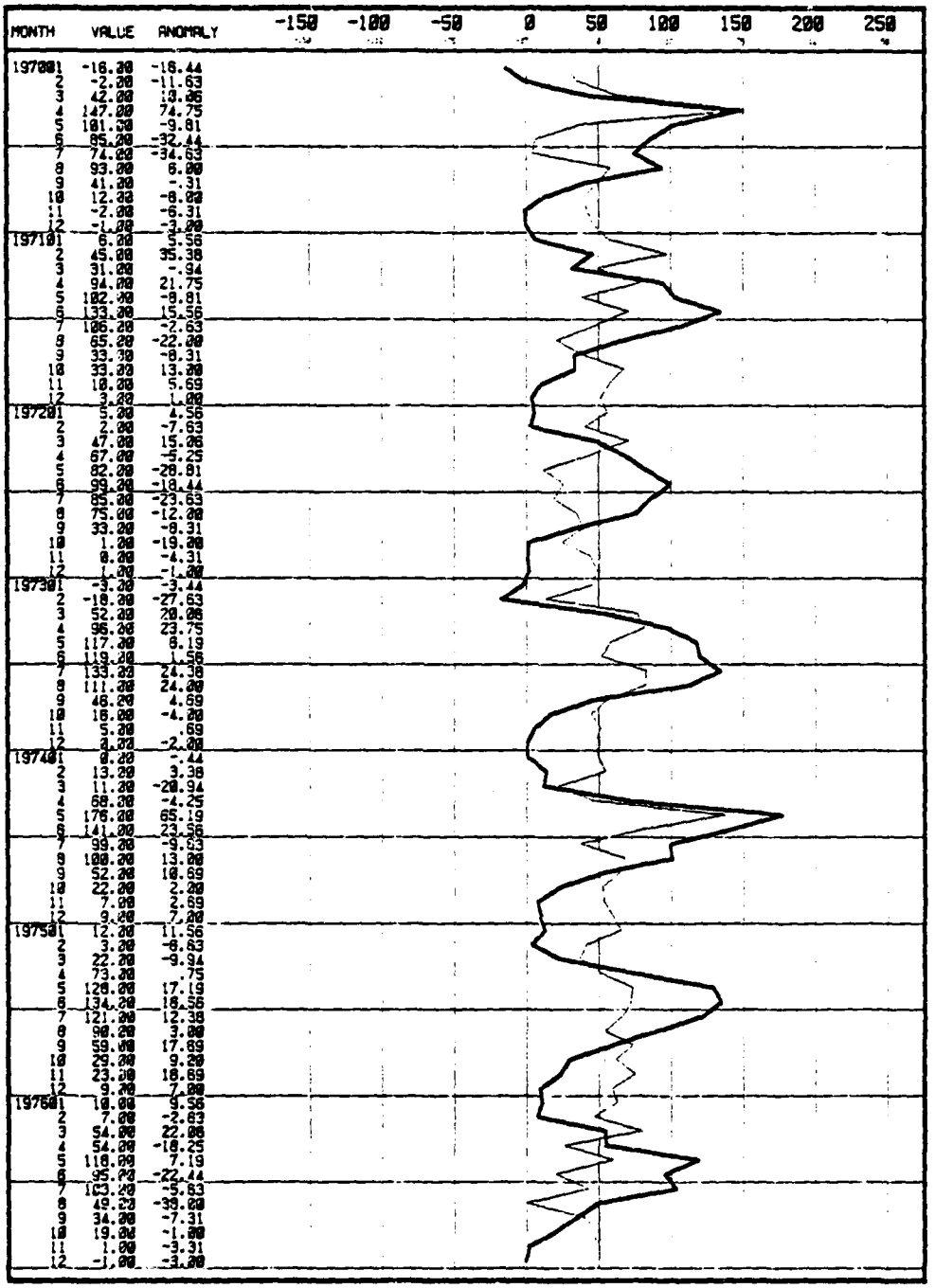
MONTH	VALUE	ANOMALY
196301	5.00	4.56
2	1.00	-6.63
3	12.00	-19.94
4	24.00	-48.25
5	65.00	-45.81
6	105.00	-12.44
7	96.00	-12.83
8	88.00	1.00
9	12.00	-29.31
10	11.00	-9.00
11	1.00	-3.31
12	-2.00	-4.00
196401	8.00	7.56
2	29.00	19.38
3	48.00	18.06
4	111.00	38.75
5	120.00	9.19
6	115.00	-2.44
7	134.00	25.38
8	98.00	11.00
9	61.00	19.69
10	13.00	-7.00
11	1.00	-3.31
12	3.00	1.00
196501	4.00	3.56
2	40.00	30.38
3	25.00	-6.94
4	26.00	-46.25
5	147.00	36.19
6	127.00	9.56
7	97.00	-11.83
8	89.00	2.00
9	38.00	-3.31
10	13.00	-7.00
11	-6.00	-10.31
12	1.00	-1.00
196601	2.00	1.56
2	12.00	2.38
3	32.00	.06
4	60.00	-12.25
5	94.00	-16.81
6	145.00	27.56
7	124.00	15.38
8	109.00	22.00
9	30.00	-3.31
10	28.00	8.00
11	-1.00	-5.31
12	3.00	1.00
196701	1.00	.56
2	17.00	7.38
3	28.00	-5.94
4	50.00	-22.25
5	122.00	11.19
6	103.00	-14.44
7	104.00	-4.83
8	83.00	-4.00
9	35.00	-6.31
10	27.00	7.00
11	0.00	-4.31
12	6.00	4.00
196801	-2.00	-2.44
2	-3.00	-12.63
3	20.00	-11.94
4	118.00	45.75
5	141.00	30.19
6	153.00	35.56
7	111.00	2.38
8	66.00	-21.00
9	54.00	12.69
10	25.00	5.00
11	8.00	3.69
12	0.00	-2.00
196901	-1.00	-1.44
2	-3.00	-12.63
3	25.00	-6.94
4	75.00	2.75
5	107.00	-3.81
6	103.00	-8.44
7	122.00	13.38
8	119.00	32.00
9	52.00	10.69
10	18.00	-2.00
11	-4.00	-8.31
12	-1.00	-3.00



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

EKMAN TSPT

BY MONTH



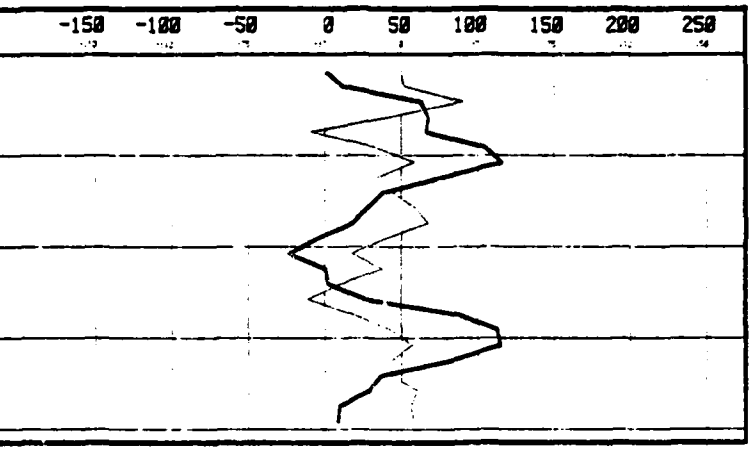
MONTH	VALUE	ANOMALY
197001	-16.00	-18.44
2	-2.00	-11.63
3	42.00	18.06
4	147.00	74.75
5	101.50	-9.81
6	85.00	-32.44
7	74.00	-34.63
8	93.00	6.00
9	41.00	-.31
10	12.00	-8.00
11	-2.00	-6.31
12	-1.00	-3.00
197101	6.00	5.56
2	45.00	35.38
3	31.00	-.94
4	94.00	21.75
5	102.00	-8.81
6	133.00	15.56
7	106.00	-2.63
8	65.00	-22.00
9	33.00	-8.31
10	33.00	13.00
11	10.00	5.69
12	3.00	1.00
197201	5.00	4.56
2	2.00	-7.63
3	47.00	15.06
4	67.00	-5.25
5	82.00	-28.81
6	99.00	-18.44
7	85.00	-23.63
8	75.00	-12.00
9	33.00	-8.31
10	1.00	-19.00
11	0.00	-4.31
12	1.00	-1.00
197301	-3.00	-3.44
2	-18.00	-27.63
3	52.00	20.06
4	96.00	23.75
5	117.00	8.19
6	119.00	1.56
7	133.00	24.38
8	111.00	24.00
9	46.00	4.69
10	16.00	-4.00
11	5.00	.69
12	0.00	-2.00
197401	0.00	-.44
2	13.00	3.38
3	11.00	-20.94
4	68.00	-4.25
5	176.00	65.19
6	141.00	23.56
7	99.00	-9.63
8	100.00	13.00
9	52.00	10.69
10	22.00	2.00
11	7.00	2.69
12	9.00	7.00
197501	12.00	11.56
2	3.00	-8.63
3	22.00	-9.94
4	73.00	-.75
5	126.00	17.19
6	134.00	18.56
7	121.00	12.38
8	90.00	3.00
9	59.00	17.69
10	29.00	9.00
11	23.00	18.69
12	9.00	7.00
197601	10.00	9.56
2	7.00	-2.63
3	54.00	22.06
4	54.00	-18.25
5	118.00	7.19
6	95.00	-22.44
7	103.00	-5.63
8	49.00	-38.00
9	34.00	-7.31
10	19.00	-1.00
11	1.00	-9.31
12	-1.00	-3.00

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

EKMAN TSPT

BY MONTH

MONTH	VALUE	ANOMALY
197701	0.20	-.44
2	11.20	1.38
3	62.20	30.06
4	67.20	-5.25
5	66.20	-44.81
6	104.30	-13.44
7	115.20	6.38
8	75.00	-12.00
9	37.00	-4.31
10	27.00	7.00
11	17.00	12.69
12	-6.30	-8.20
197801	-24.20	-21.44
2	0.00	-9.63
3	2.20	-29.94
4	26.00	-46.25
5	87.20	-23.81
6	112.00	-3.44
7	114.30	5.38
8	82.00	-5.00
9	36.00	-5.31
10	28.20	8.00
11	9.20	4.69
12	0.20	6.70



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SVERDRUP TRANSPORT BY MONTH

MONTH	VALUE	ANOMALY
196301	.07	.19
2	0.00	-.04
3	-.12	-.04
4	-.02	-.96
5	-.20	-1.16
6	1.13	-.22
7	.58	-.96
8	1.13	-.35
9	.03	-.97
10	-.02	-.59
11	0.00	-.04
12	-.00	-.04
196401	-.13	-.02
2	.62	.58
3	.19	.27
4	.58	.44
5	-.66	-1.54
6	.46	-.89
7	1.07	-.45
8	1.15	-.33
9	1.21	.21
10	.25	-.32
11	-.01	-.05
12	-.49	-.45
196501	-.10	-.07
2	.37	.33
3	.04	.12
4	-.03	-.17
5	1.83	.95
6	.31	-1.04
7	.67	-.85
8	.72	-.76
9	.38	-.64
10	.27	-.38
11	-.10	-.22
12	-.03	.01
196601	-.15	-.04
2	-.16	-.20
3	-.65	-.57
4	.77	.63
5	.22	-.66
6	1.17	-.10
7	.09	-1.43
8	.86	-.62
9	.29	-.71
10	.64	.08
11	-.00	-.12
12	-.13	-.09
196701	-.07	.04
2	.30	.34
3	-.75	-.67
4	-1.10	-1.24
5	.66	-.22
6	.92	-.43
7	1.68	.16
8	1.48	-.02
9	.82	-.18
10	.58	.82
11	.11	.07
12	.14	.18
196801	.02	.14
2	-.13	-.17
3	-.31	-.23
4	1.22	1.08
5	-.46	-1.34
6	1.27	-.08
7	.81	-.71
8	.07	-1.42
9	.77	-.23
10	.33	-.24
11	-.28	-.30
12	-.12	-.08
196901	-.12	-.01
2	-.30	-.34
3	.12	.20
4	-.33	-.47
5	.85	-.03
6	.45	-.90
7	2.92	1.40
8	3.55	2.07
9	1.48	.48
10	.33	-.24
11	.60	.56
12	-.01	.03

NOAA-NMFS. PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

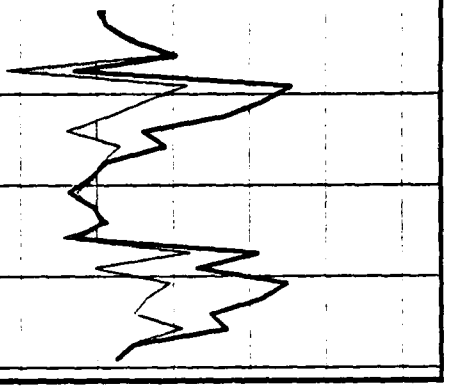
SVERDRUP TRANSPORT BY MONTH

MONTH	VALUE	ANOMALY
197801	-.66	-.55
2	-.02	-.00
3	.14	.22
4	-.07	-.21
5	1.11	.23
6	1.14	-.21
7	1.94	.42
8	1.88	.48
9	1.47	.47
10	.39	-.10
11	-.09	-.13
12	-.13	-.03
197901	.00	.20
2	.03	-.01
3	-.65	-.57
4	-.62	-.76
5	.08	-.00
6	.54	-.81
7	1.20	-.32
8	.77	-.71
9	.68	-.32
10	.66	.10
11	.10	.06
12	0.00	.04
197201	-.19	-.00
2	-.15	-.19
3	-.16	-.00
4	.38	.24
5	1.33	.45
6	2.01	.66
7	1.66	.14
8	1.56	.00
9	.81	-.19
10	.10	-.47
11	.01	-.03
12	-.11	-.07
197301	-.10	-.07
2	.02	-.02
3	.13	.21
4	1.24	1.10
5	1.66	.78
6	2.35	1.00
7	1.84	.42
8	1.81	.39
9	.90	-.12
10	.51	-.05
11	-.42	-.46
12	-.05	-.01
197401	.24	.16
2	-.12	-.16
3	-.22	-.14
4	.18	.04
5	1.56	.68
6	2.15	.80
7	1.62	.10
8	2.33	.85
9	1.70	.70
10	1.19	.63
11	.04	-.20
12	-.07	-.03
197501	.02	.14
2	-.10	-.14
3	-.13	-.05
4	.18	.04
5	2.00	1.12
6	2.18	.83
7	1.46	-.06
8	1.92	.44
9	2.23	1.23
10	.30	-.27
11	.21	.17
12	-.01	.05
197601	-.01	.11
2	.06	.02
3	.56	.64
4	-.00	-.22
5	2.37	1.49
6	1.65	.30
7	2.00	.56
8	.75	-.73
9	1.25	.25
10	.95	.39
11	.00	.04
12	.21	.25

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SVERDRUP TRANSPORT BY MONTH

MONTH	VALUE	ANOMALY
197701	0.00	.12
2	.12	.00
3	.43	.51
4	1.02	.80
5	-.30	-1.10
6	2.53	1.10
7	2.10	.66
8	1.66	.10
9	.59	-.41
10	.00	.32
11	.11	.07
12	-.06	-.04
197801	-.36	-.27
2	-.05	-.09
3	.06	.14
4	-.31	-.45
5	2.09	1.21
6	1.30	-.05
7	2.47	.95
8	2.14	.66
9	1.48	.48
10	1.60	1.12
11	.47	.43
12	.24	.20



AD-A085 040 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 8/3
SEA LEVEL VARIATIONS AT MONTEREY, CALIFORNIA.(U)
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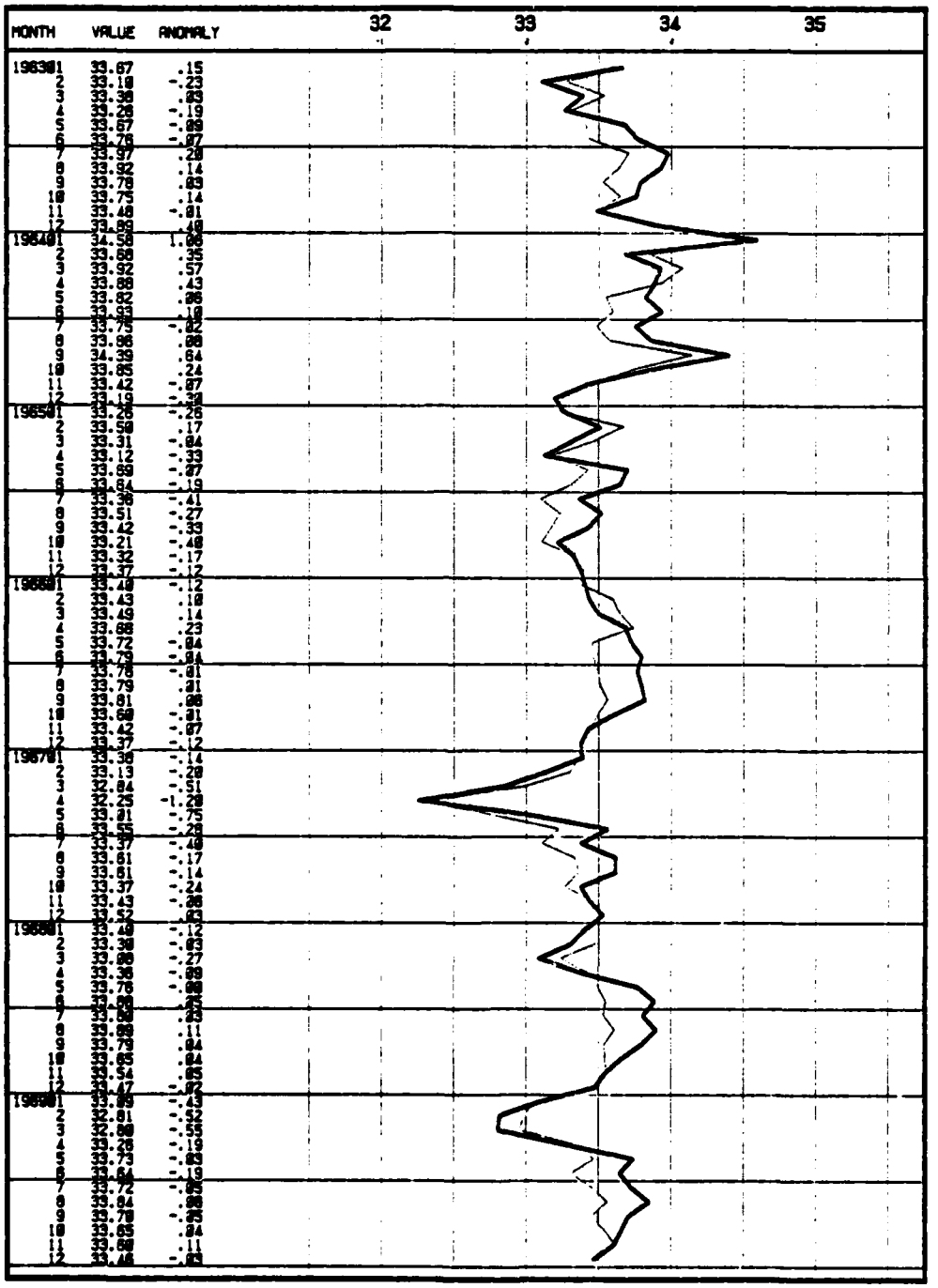
NOAA-NMFS, PACIFIC ENVIRONMENTAL GROUP, MONTEREY, CALIFORNIA

SALINITY — PACIFIC GROVE, CA — BY MONTH



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SALINITY — PACIFIC GROVE, CA — BY MONTH

MONTH	VALUE	ANOMALY
1976 1	33.21	-.31
2	32.98	-.37
3	33.23	-.12
4	33.89	.38
5	34.10	.34
6	33.95	.12
7	34.20	.29
8	33.99	.21
9	33.92	.17
10	33.63	.02
11	33.32	-.17
12	33.38	-.19
1977 1	33.51	-.01
2	33.58	.23
3	33.87	.52
4	33.92	.47
5	33.94	.18
6	34.09	.26
7	33.31	.14
8	33.58	-.22
9	33.49	-.26
10	33.61	.00
11	33.59	.10
12	33.48	-.01
1978 1	33.52	-.00
2	33.62	.29
3	33.61	.26
4	33.55	.10
5	33.92	.16
6	33.85	.02
7	33.68	-.11
8	33.67	-.11
9	33.72	-.03
10	33.53	-.26
11	33.43	-.06
12	33.51	.02
1979 1	33.51	-.01
2	33.29	-.04
3	33.14	-.21
4	33.54	.09
5	33.85	.09
6	33.78	-.05
7	33.36	.19
8	33.93	.15
9	33.58	-.17
10	33.73	.12
11	33.64	.15
12	33.65	.16
1980 1	33.47	-.05
2	33.62	.29
3	33.58	.21
4	33.49	.04
5	33.96	.20
6	34.10	.27
7	33.93	.16
8	33.82	.04
9	33.80	.05
10	33.69	.08
11	33.68	.17
12	33.68	.19
1981 1	33.81	.29
2	33.28	-.05
3	33.28	-.07
4	33.57	.22
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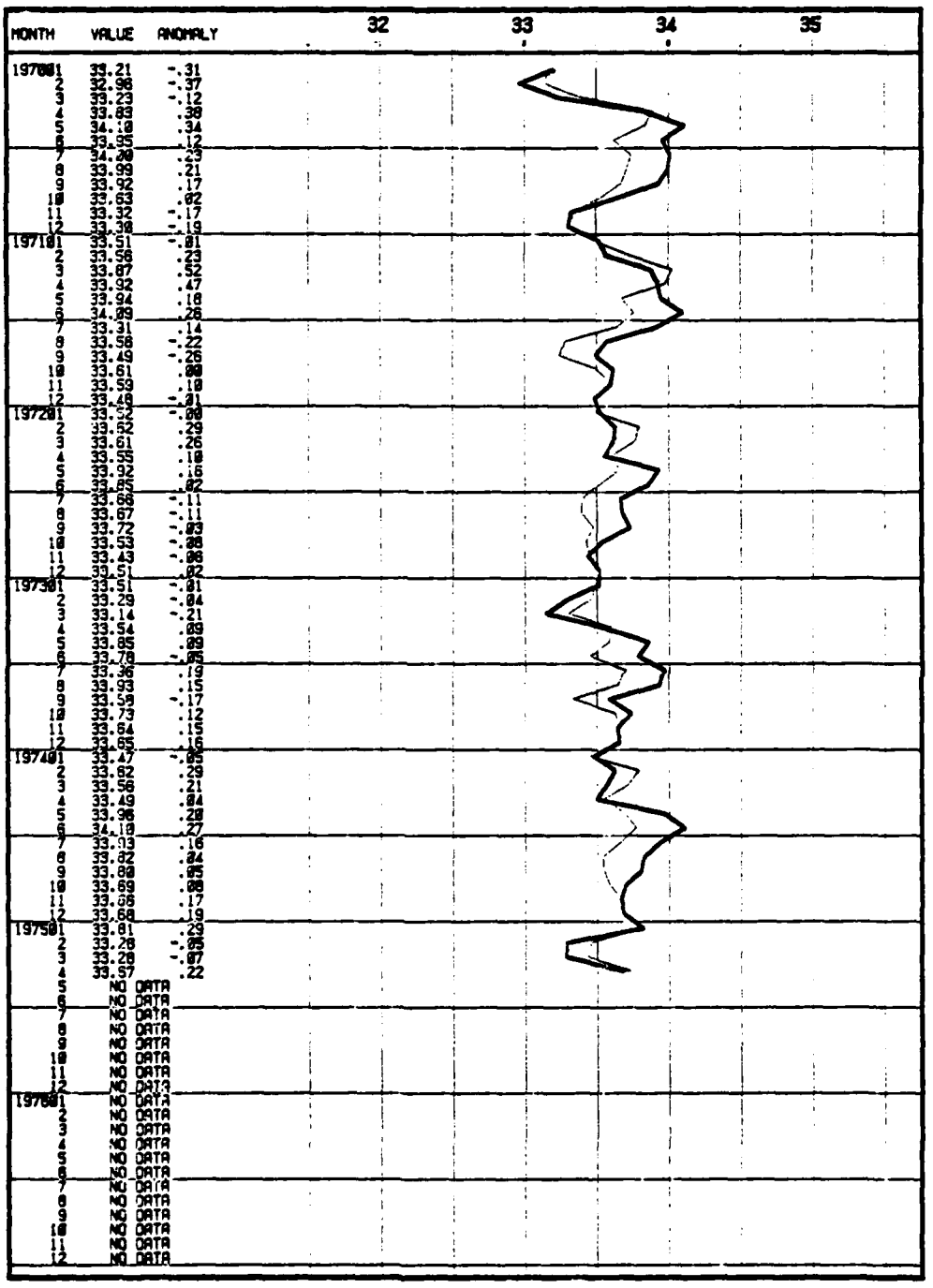


NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

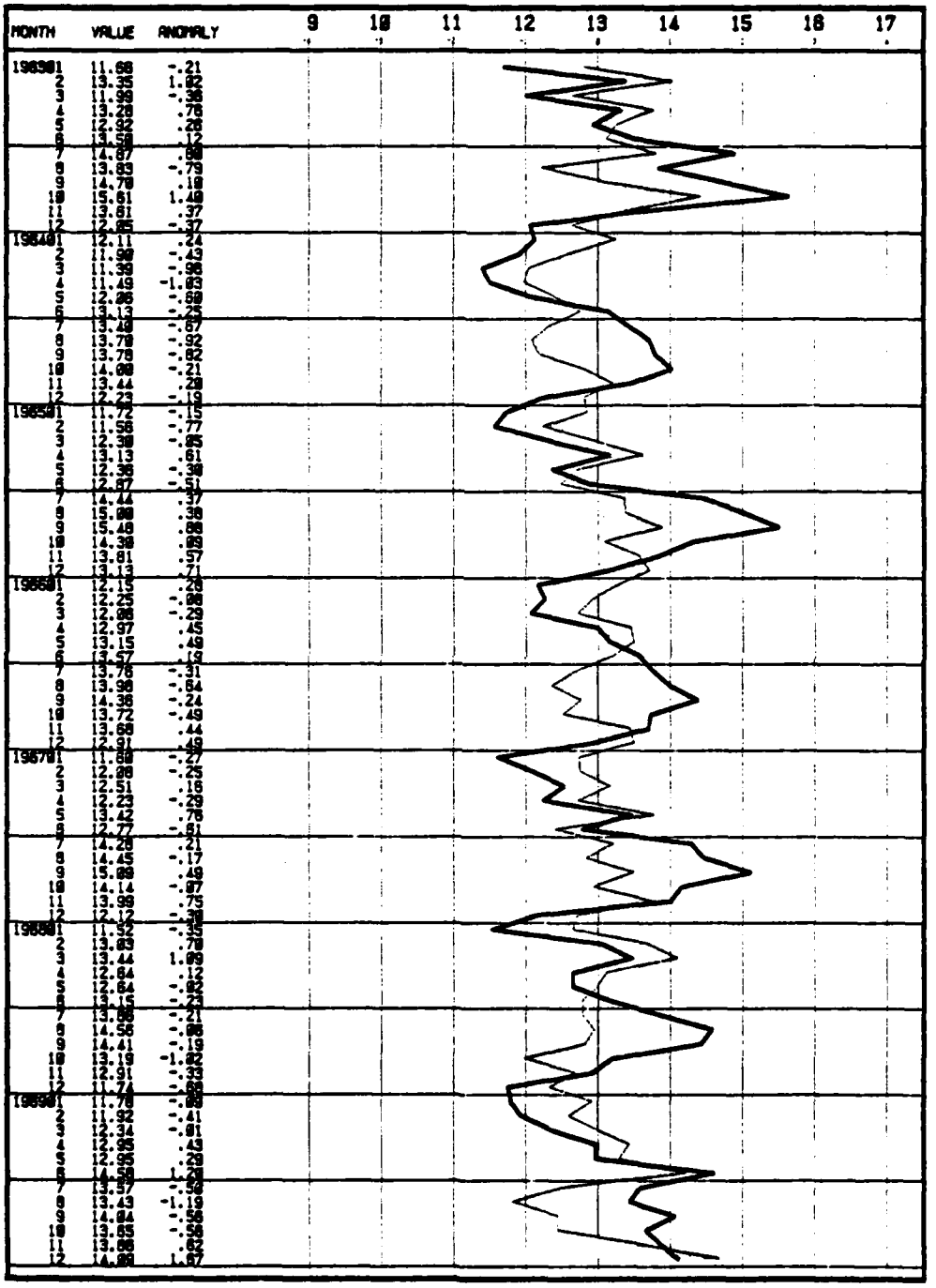
SALINITY PACIFIC GROVE, CA BY MONTH

MONTH	VALUE	ANOMALY	32	33	34	35
197701	NO	DATA				
2	NO	DATA				
3	NO	DATA				
4	NO	DATA				
5	NO	DATA				
6	NO	DATA				
7	NO	DATA				
8	NO	DATA				
9	NO	DATA				
10	NO	DATA				
11	NO	DATA				
12	NO	DATA				
197801	NO	DATA				
2	NO	DATA				
3	NO	DATA				
4	NO	DATA				
5	NO	DATA				
6	NO	DATA				
7	NO	DATA				
8	NO	DATA				
9	NO	DATA				
10	NO	DATA				
11	NO	DATA				
12	NO	DATA				

NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SST PACIFIC GROVE, CA BY MONTH

MONTH	VALUE	ANOMALY
195801	11.68	-.21
2	13.35	1.02
3	11.99	-.36
4	13.28	.76
5	12.92	.26
6	13.58	.12
7	14.87	.80
8	13.83	-.79
9	14.78	.10
10	15.61	1.49
11	13.61	.37
12	12.85	-.37
195901	12.11	.24
2	11.99	-.43
3	11.39	-.96
4	11.49	-1.03
5	12.86	-.59
6	13.13	-.25
7	13.40	-.67
8	13.78	-.92
9	13.78	-.82
10	14.08	-.21
11	13.44	.20
12	12.23	-.19
196001	11.72	-.15
2	11.56	-.77
3	12.38	-.85
4	13.13	.61
5	12.36	-.38
6	12.87	-.51
7	14.44	.37
8	15.08	.38
9	15.48	.88
10	14.38	.89
11	13.81	.57
12	13.13	.71
196101	12.15	.28
2	12.25	-.08
3	12.08	-.29
4	12.97	.45
5	13.15	.49
6	13.57	.19
7	13.76	-.31
8	13.98	-.84
9	14.36	-.24
10	13.72	-.49
11	13.88	.44
12	12.91	.49
196201	11.88	-.27
2	12.28	-.25
3	12.51	.16
4	12.23	-.29
5	13.42	.76
6	12.77	-.81
7	14.28	-.21
8	14.45	-.17
9	15.08	.48
10	14.14	-.87
11	13.99	.75
12	12.12	-.38
196301	11.52	-.35
2	13.03	.78
3	13.44	1.09
4	12.64	.12
5	12.64	-.82
6	13.15	-.23
7	13.88	-.21
8	14.56	-.06
9	14.41	-.19
10	13.19	-1.02
11	12.91	-.33
12	11.74	-.88
196401	11.78	-.89
2	11.92	-.41
3	12.34	-.81
4	12.95	.43
5	12.95	.29
6	14.58	1.28
7	13.57	-.50
8	13.43	-1.19
9	14.84	-.56
10	13.85	-.56
11	13.66	.62
12	14.81	1.57



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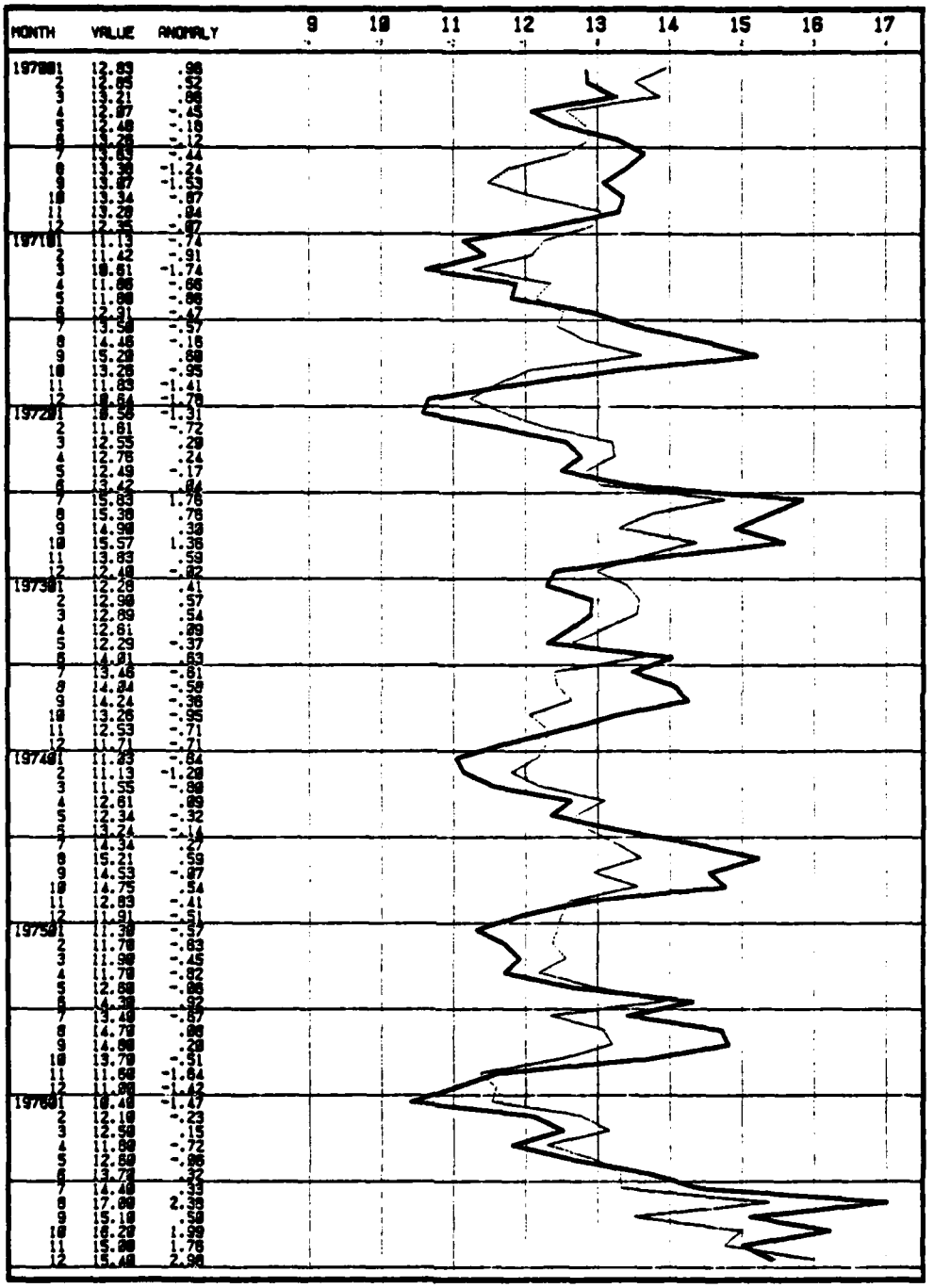
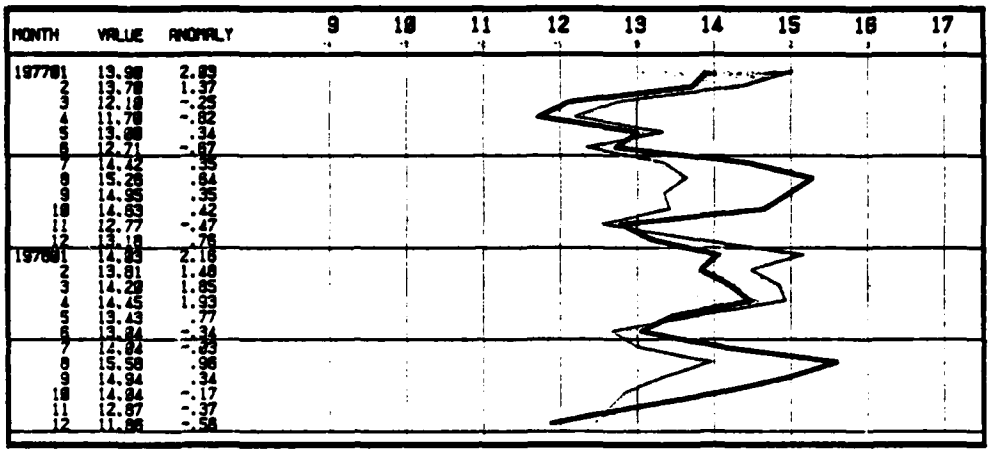
SST PACIFIC GROVE, CA BY MONTH



NOAA-NMFS.PACIFIC ENVIRONMENTAL GROUP. MONTEREY. CALIFORNIA

SST PACIFIC GROVE. CA BY MONTH

MONTH	VALUE	ANOMALY
197701	13.98	2.83
2	13.78	1.37
3	12.18	-.25
4	11.78	-.82
5	13.00	.34
6	12.71	-.07
7	14.42	.35
8	15.28	.84
9	14.95	.35
10	14.63	.42
11	12.77	-.47
12	13.10	-.78
197801	14.89	2.16
2	13.81	1.48
3	14.29	1.85
4	14.45	1.93
5	13.43	.77
6	13.84	-.34
7	12.94	-.83
8	15.58	.98
9	14.94	.34
10	14.84	-.17
11	12.87	-.37
12	11.86	-.58



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Oregon State University
Corvallis, Oregon 97331

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Oregon State University
Corvallis, Oregon 97331

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School of Oceanography
Oregon State University
Corvallis, Oregon 97331

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School of Oceanography
Oregon State University
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